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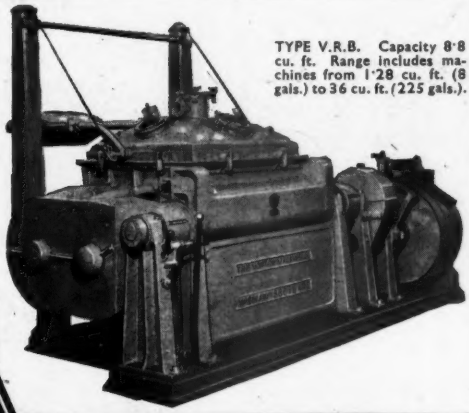

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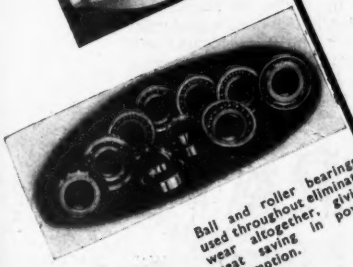

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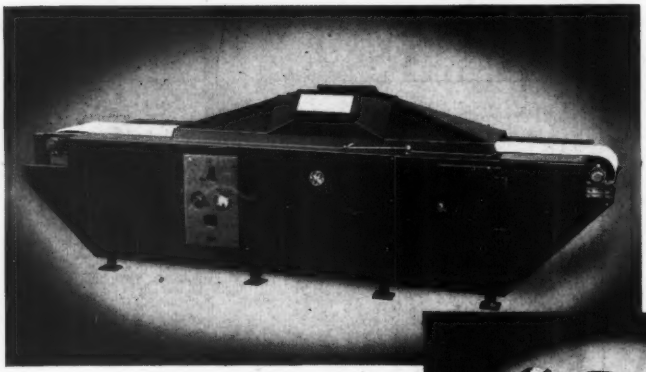

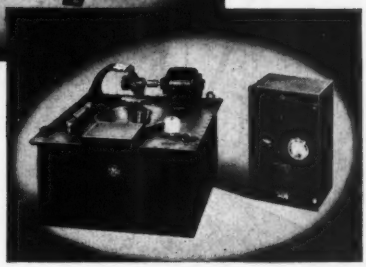

Above: Victor Visual Inspection X-Ray Unit with typical conveyor system.

At right: The Transformer and Control Panel of the Victor Visual Inspection Unit.

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Before June is out . . . .

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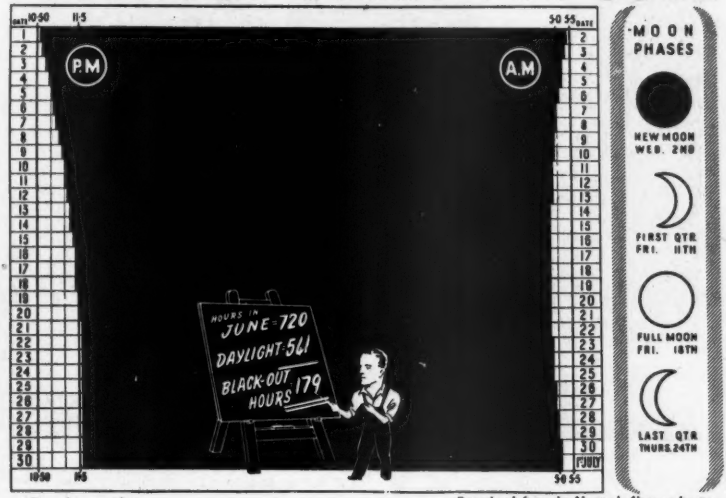

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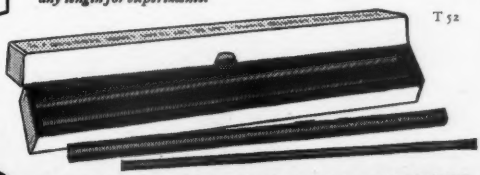

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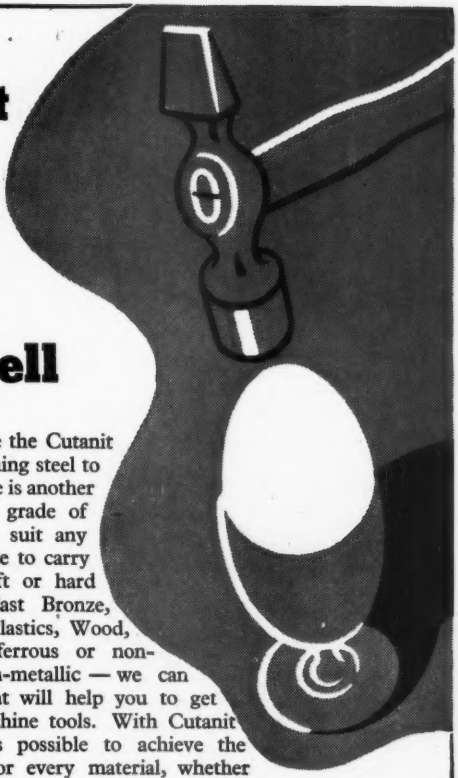

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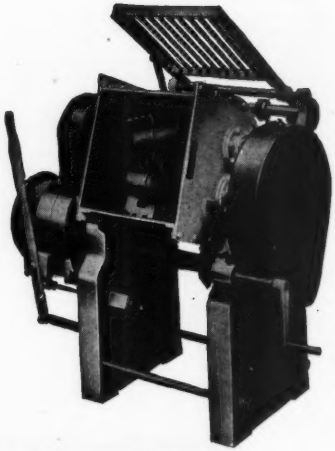

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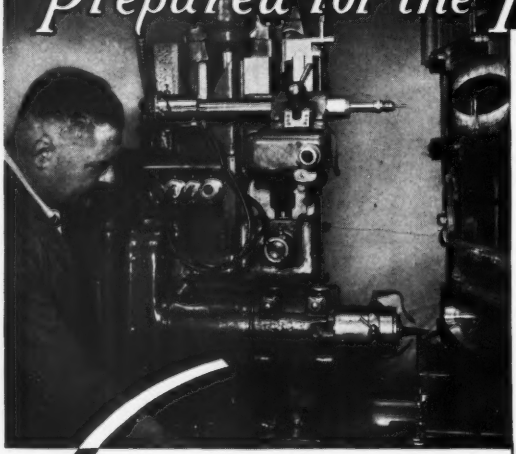

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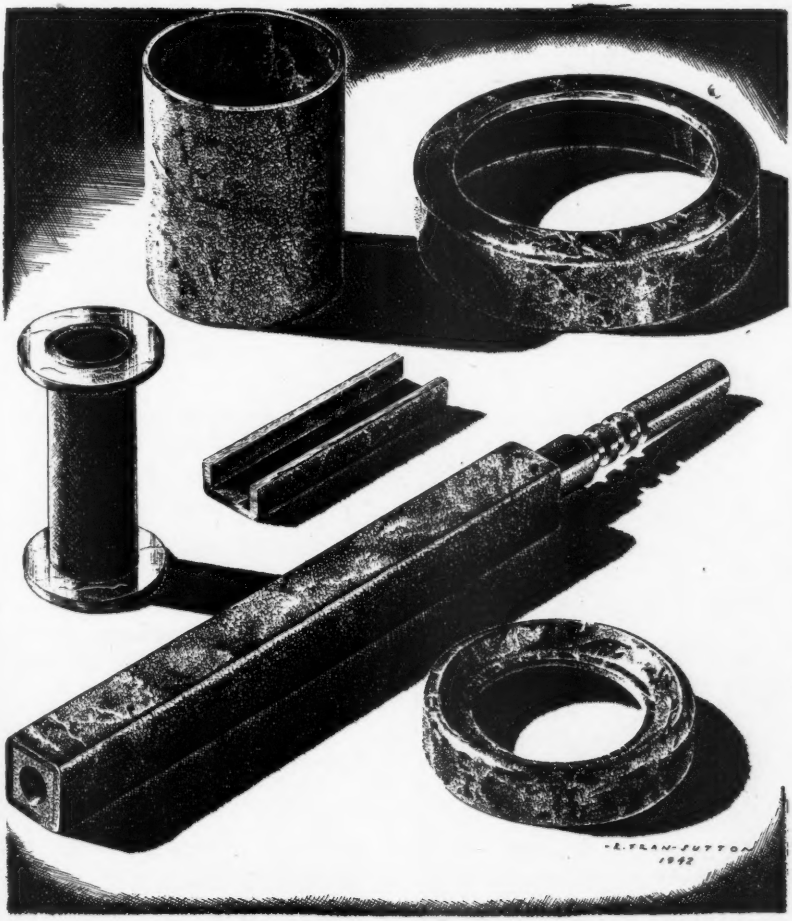

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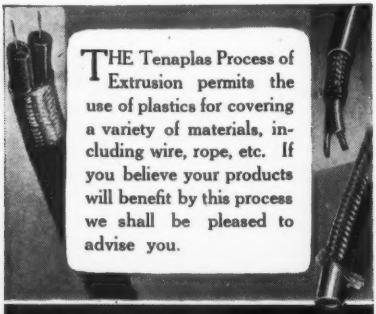
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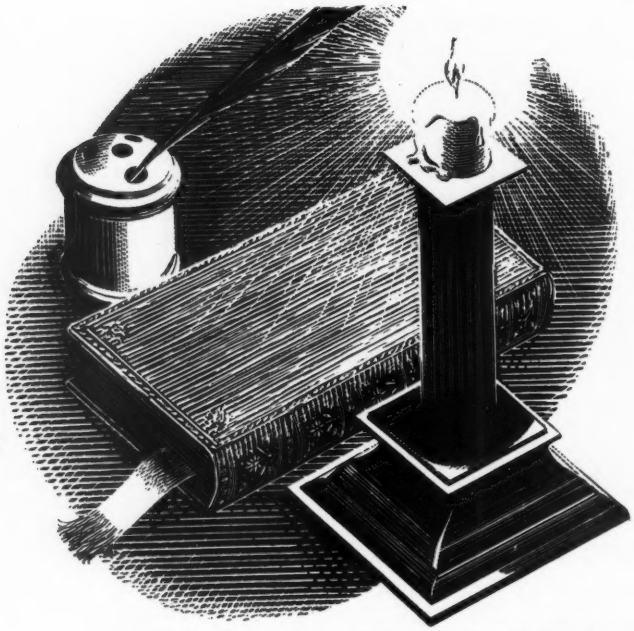

"And thus ends my Journal, I being not able to do it any longer, having done so now so long as to undo my eyes every time I take pen in hand."
SAMUEL PEPYS, 1669

TO-DAY we take that inestimable boon—electric light—very much for granted. How many of us realise, for example, the part Bakelite Plastics play in bringing electric light to almost every home and factory in the land?

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Vol. VII. No. 73 JUNE, 1943

Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

Proprietors - - TEMPLE PRESS LIMITED
Managing Director - ROLAND E. DANGERFIELD

Editor - M. D. CURWEN, B.Sc., A.I.C.
Offices - Bowling Green Lane, London, E.C.1

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NOTICES

All instructions, matter and passed proofs for all kinds of advertisements must reach the Head Office of "PLASTICS" by the 24th of each month to ensure insertion in the following month's issue.

TERMS—Monthly accounts, strictly net; due when rendered.

"PLASTICS" is published in London, England, at the beginning of each month.

Head Offices:
Bowling Green Lane, London, E.C.1.
Inland Telegrams - - "Pressimus, Smith, London."
Cables - - - - - "Pressimus, London."
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The fact that goods made of raw materials in short supply because of war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

EDITORIALS

Winged Strength

OF all the advances, known and hush-hush, that have been made in the plastics industry during war-time on a practical scale, that of resin-bonded wood and plywood has been the biggest and most spectacular of all.

In what may be called the "high-class" section of resin-treated veneers, that of impregnated sheet and board for electrical work, the market for plastics has long been assured. It was in the more general field of construction that progress was slow, for there was, perhaps, a natural resistance by the older industries, with no scientific background and age-long traditions, to the adoption of new materials. Moreover, in the wood-working industries there was the additional difficulty of altering, however slightly, their working conditions.

Even before the war, however, the plywood industry and, indeed, the furniture manufacturers had begun to adopt the new synthetic glues and impregnants. Plywood, instead of being the poor relation in the wood-working industry, leaped to the forefront as a material of construction of the first order.

Soon we heard talk of the so-called "plastic" aircraft of the U.S.A., a resin-bonded laminated structure shaped on a former and "cured" in an autoclave. After the outbreak of war these were made on a production scale. In this country a similar process was in full swing, producing small dinghies for the Navy, while great structures of thick, flat, resin-bonded plywood were being made for our 100-ft. motor torpedo boats. Gliders using similar raw material are now being turned out in their hundreds and great transport planes are being designed.

But for us the apotheosis may be said to be reached with the Mosquito—bomber and fighter-bomber, the fastest that has yet been used under service conditions by any nation, for with it the value of two types of resin for joining their veneers or wood in the mass has been proved beyond any shadow of doubt—the one for close contact and the other as gap filler.

It is true that during the last war all aeroplanes were made of wood, but the aeroplane then consisted of a number of struts and stays which served merely as a rigid structure around which to build the wings and fuselage of doped linen. To-day the fuselage itself of the Mosquito is of wood made in two halves, so that production and the fitting of internal components are enormously simplified.

There are reasons for believing that metal has been ousted by a material which is its superior, but for the moment we need only consider the enormous gain to the country in utilizing substances other than metal and in employing an industry the workers of which had virtually been unemployed in work of national importance.

The new aircraft need not be termed a plastic aircraft, for, in truth, it is a wooden one. Neither is it built up by the technique of moulding, as we refer to the term. We need waste no tears because of this, since we have an additional technique to add to our old ones, but we can reflect that, without synthetic resins, the results would have been less good. We can also ponder, if we have the time, on what future lies before the plastics industry because of the new method of construction.

We have, at last, the wood-working industries bound to us indissolubly. They have proved the worth of synthetic resins and the plastics industry, in its turn, has raised the status not only of plywood but of wood itself, so that it ranks side by side with the metals and sometimes stands beyond them in the final analysis as a new material of superlative merit.

Realism and Research

READERS of our January and March, 1943, issues may remember our disparaging remarks on the attitude of the coal owners towards research on coal. Those remarks also applied to the Government and to Sir Evan Williams (President of the British Coal Utilization Research Association), who, in announcing the decision that £200,000 per annum for five years was to be spent on research, no doubt considered it a munificent offering.

However, the news from the research front is better, for the recent report of the Parliamentary and Scientific Committee portrays an attitude of realism towards the great problems involved. It has discovered that even as long ago as 1938 the American petroleum industry spent more than £6,000,000 per annum in research. Since that date, no doubt this sum has much more than doubled.

The Committee recommends the expansion of coal utilization research on such a scale that it will ultimately employ several thousand research workers and will involve a disbursement of funds running into several million pounds per annum.

The report also gives some figures regarding the harvest to be gathered therefrom. Thus, if the present efficiency of coal utilization can be raised from 30 per cent. to 45 per cent. within a space of 15 years (at the flat rate of 1 per cent. per annum), as much as £10,000,000 will have been saved in the first year.

As to the value of new industries that may be born of such research, there is every hope that new fibres and new plastics may add £200,000,000 a year to our national income.

"We are of opinion," states the Committee, "that action should be taken here without delay. We cannot afford to wait until after the war to prepare the necessary organizations. We attach, for example, the greatest importance to ensuring that a sufficient proportion of the chemists, physicists and engineers now employed by the Service Departments, and who will not be required after the war, should be guided into coal research and maintained there with adequate remuneration and security in preference to other lines of investigation less vital to the nation. Planning on such lines is essential in connection with the demobilization of scientists and technicians.

"Our very life as an industrial nation depends upon maintaining supplies of energy and raw materials for manufacturing processes. Our climate obliges us to use immense quantities of fuel to warm our homes and places of work. There is no possible means by which we can offset the falling productivity of our mines except by increasing the value and efficient use of the coal we are able to produce. New industries must be created to secure us against unemployment, both general and regional. New life must be given to our export trade. All these vital objectives demand coal research on a scale never before contemplated in this or any other country."

Patent Laws

WHILE we are often concerned, since this is a scientific industry, with patents themselves, it is rare that we worry ourselves with the intricacies of patent law.

A recent article in "The Manchester Guardian Weekly," however, draws universal attention to a report by a Committee of the American Senate on American patent laws, and remarks how successful is the part played by anti-trust legislation in that country in the prevention of many abuses. Direct attention is also drawn to a speech made by Mr. Joseph Berkin, a member of the anti-trust division of the U.S. Department of Justice, in which he said:—

"Try, if you will, to make an electric lamp, a glass bottle, an aluminium pot, a pair of spectacles, a radio set. These are only samples. Try to make and sell these things without first receiving permission from a private group. Try to reduce prices, to install improvements. You will either bend to the edicts of these

industrial dictators, or you will be broken. The Government is limited in the exercise of its powers to regulate our economy. The supreme law has stated clearly that 'it is beyond the power of a State under the guise of protecting the public arbitrarily to interfere with private business or prohibit lawful occupations.' Yet powers which have thus been declared contrary to the law of our country, even when exercised by a sovereign State, have been wielded by private industrial groups without a shred of public responsibility.

"Added to this domestic picture is one of even more sinister implications. Our Government may not enter into treaties with foreign countries except with the advice and consent of the Senate. Coupled with this is our cherished principle of 'open covenants openly arrived at.' Nevertheless, industrial groups without any public responsibility have been negotiating treaties with foreign groups running directly counter to the foreign policy of our country. Territories are divided; thus within the past 20 years the Monroe Doctrine has been systematically subverted by the establishment of German economic colonies in Central and South America as a result of treaties between private groups."

The "Manchester Guardian Weekly" quotes Mr. Berkin's details of the cartel arrangements of American with German groups under which the Germans promised to keep out of the United States market while the Americans undertook to leave the Latin-American market alone. The German Government was thus enabled to establish a political and military bridgehead in South America—the very thing that the foreign policy of the U.S.A. was designed to prevent.

Mr. Berkin's final words are to the point:—

"Not only has the control of foreign policy been usurped, but our domestic economy in the United States has been weakened. Cartels are dedicated to a low output-high price policy. The pillar on which the modern cartel rests is monopoly. Monopoly in turn finds its strongest weapon to-day in the patent. . . When patents are used to encourage investors and to protect infant industries they are fulfilling their primary purpose; but when they are used as a device for establishing private Governments then the time has come for action."

Candid Industries

OUR remarks regarding the latest trends of plastics publicity in the May issue of "Plastics" brings to our desk a recent copy of "Aluminum News-Letter," published by the Aluminum Company of America, with an announcement entitled "We have this to say about Plastics." It is pleasing to note that the U.S.A. are no whit behind us in broadness of outlook and that there can be, as we also pointed out, a real collaboration between plastics and metals.

Here is the text of the announcement:—

"Nothing that an aluminum man can have to say about plastics can add to their virtues or subtract from their very genuine possibilities.

"Actually, Alcoa welcomes the strides being made, technically and commercially, by this great and ingenious industry.

"This is not mumbo-jumbo. It is a distinctly pious thought.

"The more folks who get the big idea that the bright hope of industry, post-war, is to do new things in new ways . . . the more designers who really get down to cases, the better for all of us. Imagineering is a nationwide must.

"Plastics do many things better than any other material.

"Alcoa Aluminum does many things better than any other material.

"The two can team up to do a better job for you in certain situations than either could do alone.

"As for Alcoa Aluminum, busy seven days a week on war production, we can only remind you that when our strong alloys are again available you are going to have to throw your old measuring sticks into the scrap heap. New costs, new strengths, new finishes."

Metallizing Plastics

A Complete Survey and Critical Study of the Modern Methods of Metal Film Formation on Plastics for their Protection and Decoration

by E. E. HALLS

THE plastics have become so established upon their own merits in widely diverse fields of application that—at least, at first sight—the suggestion of metal coatings upon them seems to be irrelevant, and, in fact, an encroachment upon the metals of engineering that they both complement and replace. Such a view is entirely incorrect, because in practice the demands for metallized plastics is a real one, it extends their sphere of usefulness, and it often makes for economy in substituting one component for two or more.

Wide Application of Metallizing

It is not generally recognized that plastics enter into most of our industries as essential products. Materials of construction; chemical plant; packaging; electrical insulation: each one of these groups representing some of the most important applications for plastics is large in productive effort and impresses itself upon an almost unlimited number of industries, public services, etc. They may all be concerned with metallization. Constructional materials may demand special properties of reflection of light or heat, for which aluminium coatings can be useful. Chemical plant may require protection against specific corrodants, e.g., lead linings to protect against sulphuric acid or sulphuric acid spray. Packaging materials or cartons may require some addition so as to resist moisture penetration, to give protection against contents, etc. Electrical insulation may require screening against magnetic fields, high-frequency effects or radio active emanations; copper, brass or lead are used for these purposes. These are only a few illustrations from an ever-growing field. The expression "metallizing plastics" can be interpreted quite broadly. Coding by the equivalent of the gold-blocking process must be included. The inclusion of a metal sheet or foil insertion in a laminated board, with the object of affording stiffness, thermal or electrical conductivity, must not be overlooked. Rods and tubes having metal cores for strength or other reasons fall within the field in the sense of a duplex, plastic/metal material fulfilling a dual role. The proposition in general of metal inserts in moulded components, and of extruded coverings upon wires and section, will be deemed out of the scope of the present article. In general, it can be said that in normal times there is an insistent demand for metal coatings for decorative purposes, and at all times there are established applications for "protective," optical and electrical metal coatings on plastics. Although the practice is by no means new, and the number of methods employed is high, it can still be asserted that knowledge upon processes is scanty and that practical processes are in their infancy. It is proposed, therefore, to review the methods available in a practical and critical manner, indicating the merits and demerits of each. Attempts will be made to show the most apt spheres of application for the various processes, with special attention to sprayed, sputtered and evaporated metal films, and where available characteristics of the coatings will be given.

Division of the Problem

The problem of metallizing plastics, although not strictly a difficult one, is not straightforward in so far as universality of treatment is impossible. The range of plastic materials is large, the

number of modifications within a single group is appreciable, so that the number of types for consideration is almost legion. Practically all the known methods of metallization have been explored with respect to their feasibility for plastics, and many of them have found application in one direction or another. A summary of these different processes is given below in the sequence with which they will be dealt:—

1. Application of a metal powder in a varnish or lacquer medium.

2. As in (1), but with suitable modifications to yield films having good electrical conductivity.

3. Metal coatings by actual metal spraying, using "hot" pistols, and metal in wire, powder or liquid form.

4. Superficial metal layers moulded or pressed on the material, or interior layers pressed in phenolic laminated boards.

5. Superficial metal layers secured with adhesives.

6. Moulded-in metal cores for rods and tubes.

7. Metal films applied by hot branding processes.

8. Electroplated metal coatings.

9. Metal coatings electrically sputtered in vacuum.

10. Metal films evaporated in vacuum.

1. Films Applied by Means of Metal Powder in Varnish or Lacquer Medium

The metallizing of plastics through the agency of specially produced metal powders suspended in bonding media of varnish or lacquer follows the orthodox technique of the enamelling sections of industrial metal finishing departments. In the metal finishing field, such finishes are primarily decorative, but the aluminium group at least play a vital role in protection from corrosion. For plastics, also, such finishes must appear at first sight to belong to the artistic or decorative spheres. This is mainly true, and in peace-time this was quite an important application; in the post-war period it may become of even greater importance. Apart from this need for this group of finishes, are several essential demands which they can aptly fulfil, viz., for the provision of light-coloured, easily cleaned surfaces for light reflection or as a background for print, diagrams and the like; for improvement in thermal reflection or for minimizing heat absorption; for increased resistance to moisture absorption or penetration, and consequently for giving greater dimensional stability or for augmenting weather resisting properties; for equalizing the surface appearance of a miscellany of components assembled in the same unit. The technique of producing finishes through the agency of metal powder lacquers for all these finishes is virtually the same, and the main points are discussed below.

The metal powders employed are specially prepared in various grades of fineness, and the individual particle is of flat, plate-like structure. The metals commonly used are aluminium, and the coppers, brasses and bronzes. Aluminium is not only available in a very wide range of finenesses, but also in a range of brightness or polish. The coppers can be procured in a range of colours apart from that typical of the metal itself, that is, in delicate shades of red and purple. Brasses range from yellow to the rich gold of gilt metal. Aluminium bronze powder is also obtainable with its characteristic gold-like sheen.

In recent years, the aluminium powders have been available in paste form, providing a more convenient composition for incorporating with the organic medium. Its use avoids the otherwise inevitable floating of the light aluminium powder into the atmosphere and possible contamination of adjacent work, and it ensures that every particle of metal powder is "wetted" with the medium.

The "bronzing media" with which the metal powders are incorporated are in effect clear varnishes or lacquers, very pale or colourless in appearance. Originally, air drying oil types of media were employed. They were used quite extensively and satisfactorily. With one gallon of medium, up to 0.5 lb. of aluminium powder, or 1 lb. of the heavier

metals, would be incorporated, and up to 1 gallon of thinners (white spirit or turpentine). Full drying time would be 24 hours or more. Application would be by brush or spray. The mixtures had to be prepared as required, and not kept from one day to the next because they deteriorated, with loss in adhesion, difficulty in spraying, perhaps spoilt appearance and increased drying time. This is due to reaction between the metal powder and acidic (resinous) constituents in the varnish. Thus the coppers and brasses fairly rapidly form green copper salts and the aluminiums cause the formation of gelatinous or lumpy compounds.

Cellulose Lacquer Films

These oil varnish media have been superseded, probably entirely, by synthetic media. The first to be developed were the cellulose lacquer variety. These are clear and quite colourless, relatively low in viscosity and in total solids. They have now been used for a long time, although they have been augmented (not superseded) by synthetics, particularly of the glyptal or modified glyptal variety.

With the cellulose media similar proportions are used as with the oil varnishes. Both brushing and spraying mixtures can be produced, and the latter can be compounded to suit small spray guns having fine nozzles, or the larger types. Adhesion is excellent; resistance to ageing and embrittlement is also excellent, of much higher order than it is with ordinary pigmented cellulose enamels. Drying time is rapid and the finishes are hard. The ready-to-use product must still be mixed as required because the cellulose media contain sufficient acidic bodies to cause attack upon the metal powder in the liquid mixture: coppers and brasses green, and aluminiums gel, just as in the case with the oil varnish media.

The range of cellulose bronzing media has been supplemented in recent years by ready-mixed aluminium cellulose lacquers. These keep indefinitely without deterioration; two different varieties retained under observation for three years showed no thickening, and the applied films revealed no decrease in qualities when compared with those produced from new material. They enable exceedingly thin, uniform coatings to be applied, and grades are available to give "structureless" films practically indistinguishable from rolled metal. These ready-mixed lacquers are not available in the copper and brass varieties.

Synthetic varnishes of the glyptal and oil modified glyptal resin types are also used extensively for metal powder media. In the case of aluminium powders, most use is made of the ready-mixed synthetics of stoving variety. The keeping qualities of these is equal to those of the corresponding cellulose products. Short, low-temperature stoving conditions are practicable, e.g., 30 minutes at 250 degrees F., and adhesion and flexibility are excellent. Such media are thus quite practicable for application to plastics such as the phenolics, laminated or moulded.

In general, the actual finish applied can comprise two coats, the first of metal lacquer, the second of top varnish. The latter can be the same medium as used for the metal powder or one of similar composition. A drying time of from half to one hour between coats for the cellulose media is sufficient; with the stoving synthetics, each coat requires the baking operation. With the media mixed as used, the clear top lacquer is necessary, as otherwise there is some tendency for the metal powder to "handle off." With the ready-mixed varieties, or even with those prepared from aluminium paste, this shortcoming is not apparent, and the clear lacquer can be dispensed with unless a glass-like appearance is desired. Alternatively, a second coat of the metal lacquer can be used.

With the thermoplastic materials (cellulose acetate, ebonite, etc.) stoving at 250 degrees F. is obviously impracticable, and with the amino plastics it is undesirable because of the tendency to blister. The cellulose media are, therefore, rightly chosen for such materials. They are likewise preferable for vulcanized fibre, which "dries out" under oven heat and

tends to warp or otherwise distort, and even for phenolic compositions of very low grade or of thin section.

Adhesion is exceedingly good and usually adequate for service conditions. For phenolic or amino mouldings and laminated boards, which have highly finished surfaces, adhesion can be further enhanced by light abrasive blasting, using either sand or crushed steel shot. For cellulose acetate, increased adherence can be procured by giving attention to solvent balance, increasing the proportion of cellulose acetate solvent (e.g., acetone) in the mixture. On ebonite and hard rubber, and on vulcanized fibre, it has not been found necessary to take any special steps, although abrasive blasting may be resorted to if desired.

Regarding precleaning, no operations specific to plastics are required. If oil or soap have been used in machining operations such as drilling, they must be removed with appropriate washing operations, as with solvent naphtha or methylated spirit. Loose dirt and swarf must obviously be removed by means of compressed air, dusting or washing.

Decorative Effects

Antique or "oxidized" silver and gold finishes are sometimes required. Aluminium of fine grade forms the basis of silver finishes. It can be toned to a softer colour by incorporating a little white enamel of the same synthetic varnish base, or a little black to render it a fuller metallic colour. Dull or semi-bright black enamel or lacquer is then applied to "shade" the silver base, misting off gradually from full black. A final coat of top lacquer in matt or glossy sheen is applied as mechanical protection. Similarly for gold finishes the appropriate brass powder provides the base, with black shading.

There is also a demand for fancy finishes of the cracking, wrinkle and crystallizing types. The first of these can be provided in aluminium cellulose type, and the other two in stoving oil composition. They are, therefore, of restricted application.

The tables summarize some data appertaining to the aluminium cellulose and aluminium synthetic enamels employed, and to the media for metal powders in general.

Table 1.—Laboratory Characteristics of Ready-mixed Aluminium-cellulose Enamels.

Sample No.	1	2
Compositional %:		
Volatile spirit (loss in weight, 3 hours at 110°C.)	80.8	94.0
Total solids	19.2	6.0
	100.0	100.0
Physical:		
Specific gravity at 25°C.	0.951	0.858
Viscosity at 25°C., centipoises	160	125

Table 1 gives the laboratory characteristics of two ready-mixed aluminium cellulose enamels. Both of these proved to have excellent keeping qualities over a period of many months, during which they showed no signs of thickening and no signs of settlement that could not be quite easily remedied by stirring. No. 1 material is a fairly orthodox consistency

Table 2.—Laboratory Characteristics of Cellulose Media for Aluminium Powders and of Cellulose Top Lacquers.

Material	Aluminium media			Top lacquer		
Sample No.	1	2	3	1	2	3
Compositional %:						
Volatile spirit (loss in weight, 3 hours at 110°C.)	85.0	86.6	77.0	86.5	86.2	83.9
Total solids	15.0	13.4	23.0	13.5	13.8	16.1
	100.0	100.0	100.0	100.0	100.0	100.0
Physical:						
Specific gravity at 25°C.	0.870	0.880	0.941	0.884	0.925	0.892
Viscosity at 25°C., centipoises	370	115	120	1,100	926	343

Table 3.—Laboratory Characteristics of Ready-mixed Aluminium Synthetic Enamels and Top Varnish.

Material	Aluminium enamel		Top varnish	
Sample No.	1	2	1	2
Compositional %:				
Volatile spirit (loss in weight, 3 hours at 110°C.)	60.5	65.0	57.5	55.0
Total solids	39.5	35.0	42.5	45.0
	100.0	100.0	100.0	100.0
Physical:				
Specific gravity at 25°C.	0.996	0.985	0.975	0.960
Viscosity at 25°C., centipoises	32	45	145	110

for a cellulose enamel for spraying, but No. 2 material shows a very low total solid figure. Upon spraying it gave an exceedingly thin coating, but one having extraordinary covering and protective capacity. It yielded a smooth metallic-like finish, strongly adherent, hard and abrasion resisting.

Table 2 gives the characteristics of the cellulose media and top lacquers for aluminium powder. These are all satisfactory materials, but of the media, No. 2 is preferred with its lower total solids and low viscosity. The three top lacquers are of similar quality, the first two of them requiring thinning with an equal volume of thinners and a third being already in a spraying consistency.

Table 3 gives the synthetic aluminium stoving enamels ready mixed, these being of the glyptal resin type. The aluminium enamels are both very low viscosity materials with medium high total solids and gave excellent single-coat films. The top varnishes are of relatively low viscosity, and proved to give thin clear glossy coatings. It is only essential to use them when added gloss to the aluminium enamel is required. With the ready mixed materials there is no danger of aluminium metallic powder handling off the finish, as there is usually when the aluminium enamel is made from medium and powder on site. In this case the top lacquer is generally essential.

The cellulose media in Table 2 and the synthetic lacquers in Table 3 are quite suitable for use with the other metal powders, copper, brass, etc.

Types of Metallic Powder

Table 4 contains some brief test data upon the metal powders referred to in the foregoing. It shows the purity of the aluminium powders, the composition of the brass powders, and the purity of the copper powders. It also gives the moisture or loss values at 110 degrees C., inevitable with these materials; all are of the order of 1.0 per cent. Finally, it shows the fat content, an ingredient from which they are inseparable by virtue of their mode of preparation; it ranges approximately from 1.0 to 6.0 per cent

The aluminium and brass powder finishes in cellulose media naturally have had applications for phenolic panels in constructional work for the purpose of providing silver and gold appearance. These same finishes toned to give antique effects have had similar applications as well as for fitments. Black phenolic moulded telephone sets have quite satisfactorily utilized the cellulose finishes to meet demands for silver, gold, antique silver and old gold surfaces. This is noteworthy because the " handle " has to withstand much mechanical wear, as well as having to resist the effects of perspiration, while the " cradle " is subjected to severe mechanical shock. Their applications include light abrasive blasting, the metal ground coat and top lacquer, and no reports of flaking or peeling have ever been obtained. Fig. 1 shows photographically the antique silver finish on a telephone handle, and illustrates the gradation from black to aluminium shades.

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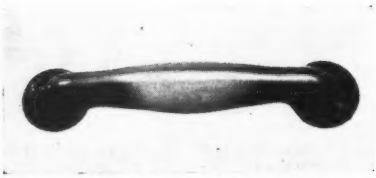

Fig. 1.—Moulded black phenolic resin telephone receiver finished "antique" silver with aluminium-cellulose lacquer.

The plain aluminium finishes, ready mixed or otherwise, cellulose or stoved synthetic, are used extensively in industrial finishing on other moulded phenolic components. One interesting application is upon engraved dials, engraved before or after finishing, and filled-in black to give sharp contrast and easy reading. Another application, also in the electrical industries, where the aluminium finishes are utilized for contrast or relief, is for panels for remote control equipments. The ready mixed cellulose products are particularly suited. Panels may consist of phenolic or amino resin laminated, preferably the former. The finish may simply comprise one or two coats of the ready mixed aluminium lacquer, followed by one of matt lacquer. Diagrams to represent the system being remote controlled are applied, usually in coloured cellulose lacquers, which adhere perfectly to the cellulose surface. Such panels can be produced neatly and clearly, and can be readily maintained clean by sponging down with soap and water.

Moisture Proofing with Aluminium Finish

The aluminium finishes have been used for moisture proofing, and are likely to find more extensive application in this direction in the post-war period. The cellulose base products have particular merits in this direction. The nitro-cellulose film itself, of course, is quite an asset in this direction, but the aluminium powder ingredient with its leafing properties markedly adds to the properties of the film in retarding the penetration of water vapour. This has been shown in several instances in practice, and one can be

Table 4.—Chemical Examination of Metal Powders.

Sample No.	1	2	3	4	5	6	7	8	9	10
	Aluminium super fine	Aluminium fine	Aluminium medium	Aluminium coarse	Gilt metal (brass) medium	Brass fine	Brass coarse	Copper fine	Copper medium	Copper coarse
Metal composition %:										
Copper	0.05	Nil	0.05	0.01	89.5	63.3	62.8	Remainder	Remainder	Remainder
Zinc	0.38	0.45	0.35	0.48	10.3	36.5	37.0	Nil	Nil	Nil
Iron	0.27	0.20	0.23	0.26	0.20	0.2	0.2	0.01	0.02	0.03
Lead	Remainder	Remainder	Remainder	Remainder	Traces	Traces	Nil	Nil	Nil	Nil
Silicon					—	—	—	Nil	Nil	Nil
Aluminium					—	—	—	Nil	Nil	Nil
Moisture, loss 2 hours at 110°C. %	1.0	0.9	1.0	0.7	1.0	1.0	0.8	1.0	0.9	1.0
Fat and oil (ether soluble) %	5.5	6.3	1.5	1.6	1.0	0.9	1.1	1.5	1.7	1.4

Table 5.—Comparative Moisture Permeability Values of 0.0010-in. Cellulose-acetate Film (a) Unfinished, (b) Spray Cellulose Lacquered, (c) Spray Aluminium Lacquered. Values are Mgms. of Water Vapour Penetrating.

Sample No.	Finish	Period in days of exposure to 100% humidity gradient					
		1	2	3	4	7	14
1	None	80	166	216	288	458	850
2	Clear cellulose lacquer	35	65	100	131	238	462
3	Aluminium-cellulose lacquer	8	14	20	27	52	94
	For comparison:						
4	0.004-in. yellow varnished silk ..	8	15	22	31	52	110
5	0.004-in. black varnished silk ..	6	12	17	22	39	83

selected to demonstrate the fact. This concerns the membrane fixed over the acoustic diaphragm of the capsule in a telephone transmitter. Using cellulose acetate film in thicknesses from 0.0005 in. to 0.002 in., which in itself has no particular claims for moisture proofness, and is little more than a mechanical protection against dirt and liquid water, tests have shown marked improvement by lacquering and very marked moisture proofing by applying aluminium cellulose lacquer. This is demonstrated by the values given in Table 5. The "finished" specimens were produced by two thin coats. It can be seen that the aluminium lacquered material is closely equal in performance to the 0.004 in. varnished silks normally employed, and which, of course, are much thicker, with the disadvantage of greater sound-damping influence. These silks are included in the table for comparison. The values are also shown diagrammatically in Fig. 2 for clearer visualization. The values were determined by sealing the specimen over a cup containing anhydrous copper sulphate, and then exposing to an atmosphere of 100 per cent. humidity at ordinary temperatures. The effective area of film under test was 1 sq. in. Weighings were made at intervals to measure the weight of water vapour penetrating the specimen under this condition of 100 per cent. humidity.

This mode of waterproofing has numerous applications, not only for electrical and other apparatus but in normal packing applications. The possibilities of inexpensive phenolic mouldings, or of cartons and packages fabricated from card and wood pulp reinforced with synthetic resin, being filled or packed, seamed with adhesive tape, and automatically spray lacquered with aluminium medium, are very positive. The aluminium finish would also provide the background for a stamped, stencilled or otherwise applied marking. Nevertheless, other established methods, or those under development, must not be overlooked; metal foil coverings, combined foil and plastic film, or truly moisture-proof plastic material, among other methods, each has its own role in this sphere.

The moisture-proofing character of aluminium cellulose media also renders

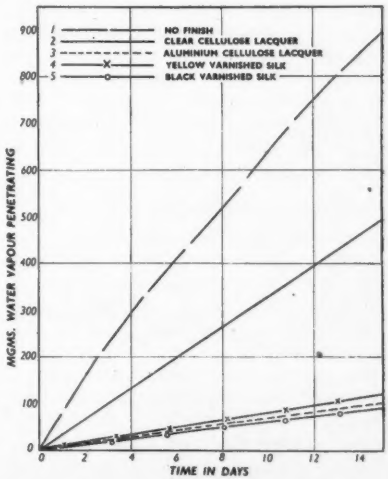

Fig. 2.—Moisture permeability of cellulose acetate, plain lacquered and aluminium lacquered, compared with varnished silk.

Table 6.—Electrical Strength Values of Organic Bonded Aluminium Powder Finishes. Tested Through Thickness of Film.

Sample No.	Base material	Surface condition of base material	Composition of finish	Electrical breakdown strength	
				Volts D.C.	Volts A.C.
1	Mild steel plate	Smooth	One coat ready-mixed aluminium stoving synthetic	< 1	< 1
2	Mild steel plate	Smooth	One coat ready-mixed aluminium stoving synthetic, one coat stoving synthetic varnish	50	—
3	Mild steel plate	Smooth	One coat stoved aluminium in oil varnish medium	3	—
4	Mild steel plate	Smooth	Two coats stoved aluminium in oil varnish medium	3	—
5	Mild steel plate	Smooth	One coat aluminium cellulose, one coat cellulose top lacquer	10 to 20	—
6	Mild steel plate	Smooth	Two coats aluminium cellulose, one coat cellulose top lacquer	10 to 20	—
7	Mild steel plate	Smooth	One coat aluminium cellulose, two coats cellulose top lacquer	—	2,000
8	Mild steel plate	Smooth	Two coats aluminium cellulose, two coats cellulose top lacquer	—	1,200
9	Mild steel plate	Smooth	One coat pigmented cellulose primer	280	200
10	Mild steel plate	Smooth	One coat pigmented cellulose primer, one coat ready-mixed aluminium cellulose	600	400
11	Mild steel plate	Smooth	One coat pigmented cellulose primer, one coat ready-mixed aluminium cellulose, one coat cellulose top lacquer	900	600
12	Structural ironwork	Rough	One coat ready-mixed aluminium stoving synthetic	< 1	< 1
13	Structural ironwork	Rough	One coat ready-mixed aluminium stoving synthetic, one coat stoving synthetic varnish	40	—
14	Structural ironwork	Rough	One coat stoved aluminium in oil varnish medium	1 to 5	—
15	Structural ironwork	Rough	Two coats stoved aluminium in oil varnish medium	2 to 5	—
16	Structural ironwork	Rough	One coat aluminium cellulose, one coat cellulose top lacquer	200	—
17	Structural ironwork	Rough	One coat aluminium cellulose, two coats cellulose top lacquer	—	550

them attractive for finishing mouldings in cellulose acetate, or objects fabricated from sheet acetate, if they have to endure open weather conditions. By their means the dimensional changes that naturally occur with atmospheric fluctuations from dry to wet and from warm to cool, or vice versa, can be materially reduced. Thus cellulose acetate becomes a suitable material for some purposes for which it would be otherwise unsuited due to dimensional movements.

Finishes and Electrical Conductance

Attempts have been made to use the metallic powder finishes, bonded with organic lacquer, for purposes involving electrical conductance. In the general sense, such attempts have failed because these finishes are relatively non-conductors. At the same time, when they are used in electrical equipment as decorative, protective or utility finishes, care must be taken to ensure that they do not lower the required insulation values on the work to which applied. These organic resin-bonded metal powder finishes differ from metal foil coatings, metal-sprayed or electrically deposited films. The particles in them are separated by an organic film of high electric strength, the value of which may range from 100 to 1,000 volts A.C. per mil of thickness, or even higher in some instances. Additionally, there is the probability of an oxide coating having insulating properties completely covering each particle. This is particularly the case with aluminium powders. Generally it is found that the "surface" electric strength, as well as the value through the film parallel to the surface, is high. Thus such sprayed coatings are useless for magnetic and electrical screening even at frequencies as low as 50 cycles. Through the thickness of the film electric strength values vary, but generally the finish must be regarded as insulating in this direction. Low electrical breakdown voltages can mainly be attributed to roughness of base metal causing rupture or very thin spots in the film, metal powder particles not properly coated with medium or not properly aligned in the finish, or to dirt or other extraneous matter in the film. To study these electrical properties, tests are best made on metal specimens,

although specific applications may require individual consideration. Some test results are summarized in Table 6 in order to illustrate the points under discussion. In this some direct and alternating current breakdown values are given for various finishes on smooth and on relatively rough base metal. The base metal formed the lower electrode, while the upper electrode consisted of a brass cylinder with radiused edges, contact area 3 sq. ins., total pressure 200 grams. Reviewing the values in some detail, it will be gathered that the nitro-cellulose binder is responsible for higher breakdown values than the stoving synthetic (glyptal resin base) or the oil varnish medium. Thus specimens Nos. 1, 3, 4, 12, 14 and 15 (one or two coats stoved aluminium synthetic or oil varnish) showed very poor electric strength, while similar finishes with corresponding top media still yielded relatively low values (Nos. 2 and 13). The aluminium celluloses with only one coat of top lacquer (specimens Nos. 5, 6 and 16) showed from relatively low to medium electric strengths, but with two coats of top lacquer (Nos. 7, 8 and 17) relatively high values. Specimens 9, 10 and 11 indicate that when sandwiched between two films of cellulose base material, the aluminium powder finish possesses an electric strength value of similar order to that of the medium without metal powder.

Electrical strength of metal powder films applied through the agency of varnish media have been illustrated only by the aluminium powders, but the comments given apply to other metal powder finishes made in a like manner.

Broadly interpreted, the data in Table 6 indicate that metal powder finishes are non-conductors in the relative sense, but that in electrical applications some attention is demanded to ensure that insulation values are not diminished. Thus it may be necessary in some cases to shield insulating panels around terminals or other inserts.

(To be continued)

Spraying of Plastics

In the May 22 issue of "Chemistry and Industry," W. E. Ballard, A.I.C., of Metal Sprayers, Ltd., deals with the interesting subject, "The Hot Spraying of Powdered Materials."

After describing the history and modern technique of spraying, with special reference to metals, he concludes his remarks with reference to plastics.

The method of hot spraying of powders, the author states, is now receiving attention for depositing coatings of bitumen, shellac, thermoplasts and thioplasts. A difficulty arises that it is not easy to obtain these substances in a finely powdered form. The rough surface normally so desirable with metal spraying appears to be less desirable in this case. If the flame is too hot or the powder feed too slow, oxidation of the powder takes place and even at somewhat lower temperatures partial decomposition is noticed. It is better, therefore, to keep the powder feed rate up and the flame volume down and arrange that the coating is first deposited in a partially plasticized form, that is, with half the particles plasticized and the other half unmelted. The coating having been achieved, it is easy to run over the surface of the film with the burner and so get a smooth coating in which the whole mass has been melted. Coatings produced in this way have the advantage that they contain no solvent and if prepared carefully are free from pinholes. It may be of interest to note that the I.C.I. has recently taken out a Patent, No. 551,339, the claim for which is the spraying of the polyethylenes by means of a powder pistol. There is mentioned a method of producing the powdered polythene by milling the material having a softening point below 110 degrees C., in a rubber mill with the rolls heated at 110 degrees C., using a small nip. When the material forms into a semi-fluid mass, cold water is passed through the rolls and a powder is obtained. In the opinion of the author, polythene is particularly suitable for spraying through a flame pistol of well-known type, because it does not partly decompose, as do most of the other polymerized materials.

INQUIRIES AND ANSWERS

(In Which is Included General Correspondence)

IMPORTANT NOTICE: If inquirers wish to receive replies by post, a stamped and addressed envelope must be included in their letter. Unless otherwise stipulated, it is understood that the submission of a problem to the Editor permits its publication in this journal.

Filling Pores in Castings

We have obtained your journal each month for some time now, and shall be very pleased if you will give us some help in the following matter.

Will you be good enough to lay the following before any Association of Plastic Manufacturers that may exist? We make a number of cast-iron cylinders, and in many cases it is necessary to grind the bore to obtain the finish required. Due to war-time conditions, it often happens that there is a fault in the casting of the bore, and the cylinder is necessarily scrapped or a rather unsatisfactory repair of the best type has to be made.

It strikes us that some of your members may be in a position to spray the rough-turned bore of our cylinders with some form of plastic, which we could subsequently finish, turn and grind if necessary. The actual limits on the diameter of the bore are not very close, but we must have a perfectly round bore which is also smooth, because we deal with fairly high pressures and the packings or leathers must have a smooth surface on which to work. It seems that a plastic would provide both of these desired conditions, whilst the cast-iron or steel cylinders would provide the necessary strength to resist the high pressures and shocks concerned.

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[EDITOR'S NOTE.—The problem bears some resemblance to the modern technique of treating porous castings to make them non-porous. Thus, a bronze casting known or suspected of being porous may be dipped in a phenolic resin solution and then cured at a suitable temperature when the hardened resin remains in the pores. This process, which is now well known and has been successfully employed, has been developed by most of the well-known resin makers, from whom details and help may be obtained. The present problem is somewhat different, since the suggestion is that the resin must not only make the cylinder non-porous but also form a smooth lining to the whole of the cylinder walls. So far as we know, a sprayed layer of resin would be most difficult to grind without resulting detachment, and it would be better to consider the resin merely as a pore filler and grind the metal interior as normally. On the other hand, it is conceivable that a resin impregnated or even moulded cylinder might be fitted as a lining, but then the problem arises whether such a structure would stand up to the shocks of, say, water under high pressure.]

Plastics for Dentures

I should value very much the name and address of a British firm offering plastic material for dental purposes, moulding by dentists in their own light pressure moulds or autoclaves. ROBIN WALKER.

Dysart.

[EDITOR'S NOTE.—Each of the following supply raw materials and give details of moulding of material for dental purposes: Bakelite, Ltd. (phenolic type); I.C.I. (Plastics), Ltd. (acrylic type); Portland Plastics, Ltd. (acrylic type).]

Laminated Polyvinyl Sheet

For some years now we have been making articles for Government shipyards from .030-in. vulcanized fibre sheet.

We have recently been advised that this material is proving unsuitable owing to it being badly affected by steam and damp, and have been asked to try and find an alternative material. We have been experimenting with Bakelite and other resin-bonded sheets, but these have proved unsuitable owing to their not being pliable enough, and to the ease with which they break in fabrication.

Can you give us any information regarding any other type of plastic sheet which would be suitable for the job? Is

Finding a range with modern scientific instruments presents no difficulty to the trained operator. Experience quickly teaches how to secure the best service the instrument can give. Certainty replaces guesswork.

So it is with the service of Imperial Chemical Industries Ltd., who offer to manufacturers a wide range of plastic materials including "Mouldrite" phenol-formaldehyde type and urea-formaldehyde type powders, resins and syrups; "Perspex" acrylic resin sheet; "Diakon" acrylic resin moulding powder; "Welvic" polyvinyl chloride compounds; nylon monofils; "Alkathene" (polythene) rod, sheet and film and polythene—P.I.B. mixture.

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P. 92A

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there any kind of polyvinyl-bonded sheet on the market?

We are at present handling the usual polyvinyl sheeting as a rubber substitute, but we are wondering if there is any laminated sheet in which polyvinyl is used instead of resin.

We enclose a sample of the fibre article to which we refer. We send this in the flat, but it has to be also formed into a tubular section of about 2-in. diameter. We should be glad of any information you could give us on this subject.

L. (B'HAM), LTD.

[EDITOR'S NOTE.—Since a stiff yet very flexible material is required, we agree that sheets of phenolic laminated material must be unsuitable, and presuming that the steam is not at 100 degrees C. or over, that a polyvinyl bonded sheet would be an improvement. The only type in existence we know is the Gelva bonded wood veneer made by Horden Richmond, Ltd. normally used for air-screw manufacture. This concern might be approached for further information. Also concerns such as BX (Plastics), Ltd., I.C.I. (Plastics), Ltd., and F. A. Hughes, Ltd., Vinyl Products, Ltd., would know of any production of fabric laminations employing polyvinyl compound as binder.

In passing, it is worth while mentioning that I.C.I., Ltd., formerly manufactured an interesting resin made by the combination of phenol, Rubbone and formaldehyde. This was employed by Micanite and Insulators, Ltd., for example, for impregnating paper to give a stiff yet flexible and "mouldable" sheet. Unfortunately, this is no longer manufactured because of the rubber situation, but the inquirer may care to keep it in mind for post-war development.]

Change of Name

We have to inform you that the name of the firm of Celluloid Printers, Ltd., has been changed to U.K. Plastics, Ltd., merely so as to provide a title which has a greater implication of the company's wide range of activity in the plastics field than had the former one.

Although printing and engraving on celluloid and other plastics has always been, and will continue to be, an important one of the company's activities, it is by no means the most important, which cover in full the manipulation and fabrication of all forms of plastics, whether in sheet, rod or tube.

In order to preserve our established goodwill, a new subsidiary company, Celluloid Printers, Ltd., came into existence at the time the change of name was effected. Both companies will be under exactly the same direction, management and control as hitherto, although in the future, orders and contracts will be accepted and placed by U.K. Plastics, Ltd.

We shall appreciate it if our customers and suppliers will record the fact of this change, and realize that when dealing with U.K. Plastics, Ltd., they are still receiving the service of the former firm of Celluloid Printers, Ltd., and that since there has merely been a change of name and absolutely no change of directors, management nor any reconstruction whatsoever, all existing contracts stand with the company under its new name exactly as they did under the old.

U.K. PLASTICS, LTD.

The Gauge and Tool Makers' Association, Ltd.

We have received the following information regarding the above association from the secretary, Mr. G. T. Beach:—

(a) Change of Telephone Number

The telephone number of the Gauge and Tool Makers' Association is now Regent 3451-2.

The offices remain at Standbrook House, 2-5, Old Bond Street, London, W.1.

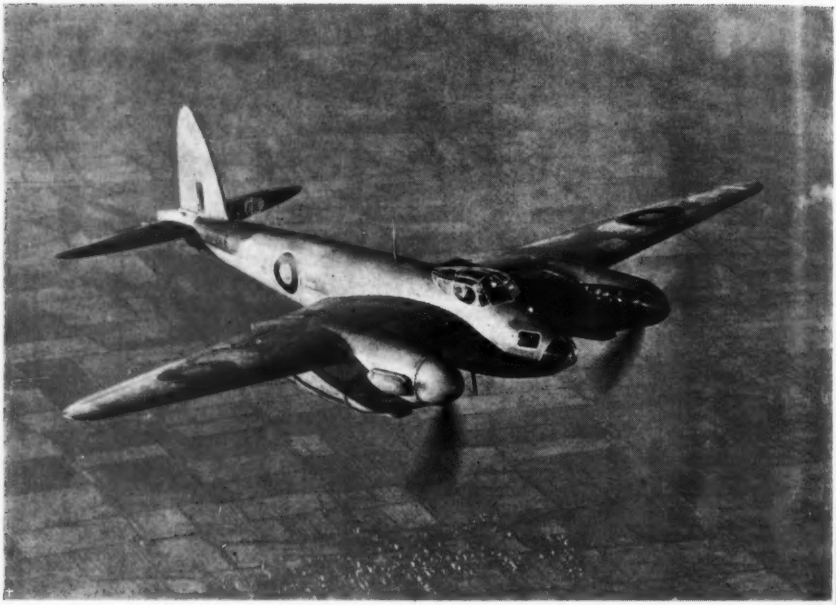
(b) Annual General Meeting

This year's annual general meeting of the Association will be held on Wednesday, July 7, to receive a report from the chairman upon activities during the past session, to approve the accounts, to appoint auditors, to consider future policy, etc.

(c) Booklet of Aims and Objects

Copies of the Association's booklet of Aims and Objects, which includes details of the annual subscriptions and a complete list of the existing members, may be obtained on application to the secretary, Mr. Gilbert T. Beach.

MOSQUITO—



—FASTEST IN THE WORLD is Bonded with Synthetic Resin

THE fastest aeroplane in the world to-day is built of plywood—plywood bonded with synthetic glues. It is, indeed, a proud and important moment for the plastics industry to learn that the de Havilland Mosquito bomber, so fast that it has been to Berlin with 2,000 lb. of bombs and back again (without them) in less time than any other fighter, relies not on metal for its main construction, but on a combination of other materials which has now proved its worth. For a number of reasons, the wood-resin structure has become of tremendous importance to our war effort. We are indebted to our companion journal, "The Aeroplane," for the following data.

Design and Structure

Aerodynamically, the Mosquito is a two-motor high mid-wing monoplane with fully retractable undercarriage and single fin and rudder. The radiators are mounted in the centre-section of the wing between the fuselage and the engine nacelles, where they offer remarkably little drag.

Structurally, the Mosquito is built almost entirely of wood. The wings are of stressed skin wooden construction, the fuselage similar to that of the Albatross

except that it is assembled in two halves, split along the longitudinal axis from nose to tail, top and bottom. This feature makes installation of equipment remarkably easy.

The de Havilland design team is one of the best-balanced units in the country, and possibly anywhere. Thus the selection of wood for construction is particularly interesting, especially in view of the fact that the D.H.95, the Flamingo, which was in production when war broke out, was of all-metal stressed skin construction.

Three primary reasons governed the decision to adopt wood for construction. They were:—

(i) For quickness of design and to get the prototype into production as soon as possible.

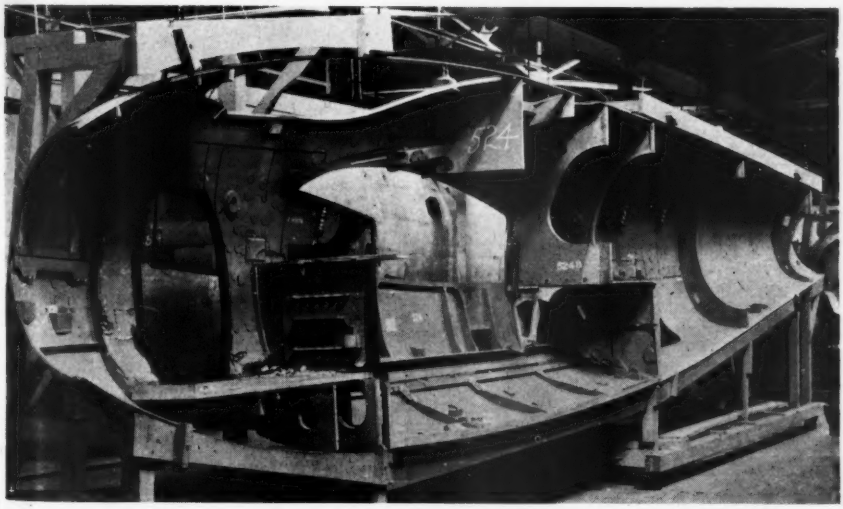
(ii) To tap materials not being fully used.

(iii) To employ new labour.

At the time when the production of the Mosquito began there were said to be some 12,000 skilled woodworkers unemployed. Furthermore, use of wood made possible greater dispersal of production, greater ease of repair and increased buoyancy should a forced descent on the water be necessary. In fact, Mosquitos have floated for many hours at sea with the cockpit partly out of the water.

Another factor which has proved valuable in wood construction is the surface finish which can be secured. In these days of camouflage paint this might not be considered of much importance, especially as a "velvet" black night-flying coat was found to reduce the speed by about 16 m.p.h. without any further alteration. But the smoothness of the skin, free from rivets or ripples, helps greatly to maintain performance at high speeds. The falling off in speed, sometimes caused by the rippling of the skin and small leaks which develop at the edges of metal plates after a time in service, naturally does not occur with a machine of the Mosquito's construction.

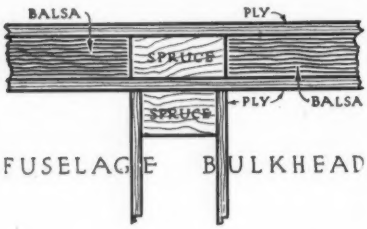
When the design was begun little was known about how wooden construction

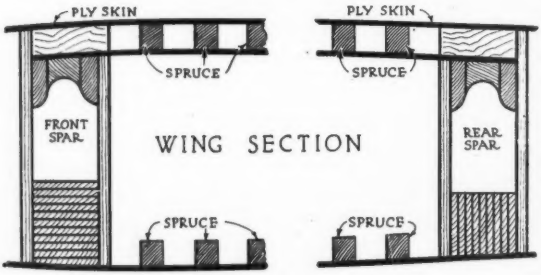


The starboard half of the fuselage of a de Havilland Mosquito II showing the way in which the complete assembly is made ready for the installation of equipment before the halves are joined together.

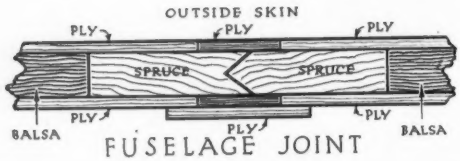
would withstand enemy fire, except for the experience of 1914-18. The results in service have been most enlightening. Bullets or fragments of A.A. or cannon shell go through the structure like a knife through cheese. They usually emerge the other side, leaving holes little bigger than the missiles. And because wood is bulkier than metal for the same strength the bullet holes are a smaller proportion of the total and so weaken the structure less. Repairs are comparatively easy by any skilled carpenter. Even a damaged wing tip can be cut off and a new section butt-jointed into place, a valuable feature in war.

Thus wood construction has many advantages, and for a company such as de Havilland, which has had long experience in woodwork for aircraft, wood became a natural choice.





The three drawings shown here of fuselage bulkhead, fuselage joint, and wing section without metal inclusion—



—show how important is the need for perfect glueing. The introduction of synthetic resins has enabled the country to employ wood on a large scale.

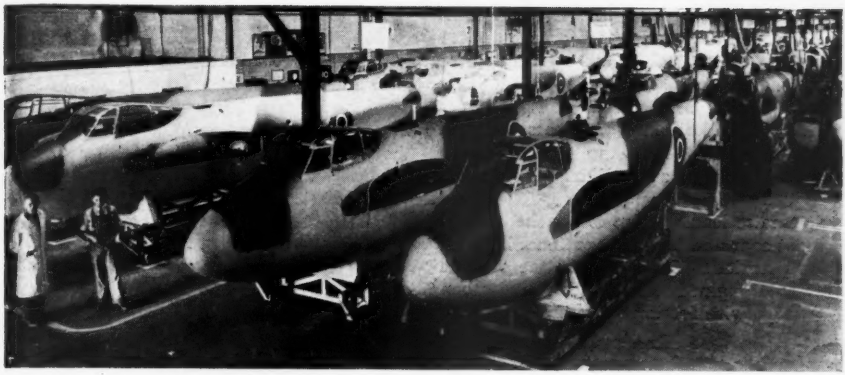
The Synthetic Glues

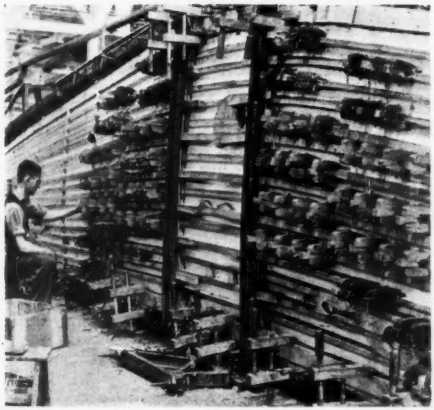
During the war of 1914-18 nearly all aircraft were wooden structures glued together by means of casein glue. The value of this excellent and easily applied adhesive has long been admitted, and, indeed, until recently the new Mosquitos had been so bonded. To-day it is realized that, under certain conditions, for instance, under humid conditions, the purely synthetic types are an improvement. So it is that the change over to the latter is now an established fact, and the phenolic bondings, in solid film or liquid form, or the urea-formaldehyde glue, Beetle W, are used widely for bonding plywood laminations or other close-contact operations. For the very different operation of gap adhesion these glues are not suitable, and wide use is made of the specially devised glues, such as the urea Beetle A.

Wings

The wings of the Mosquito are built up in a single section from tip to tip. The centre portion carries the radiators and engine mountings. The fuselage drops on top of the centre section and is secured by four massive pick-up points.

There are two box spars with ply webs

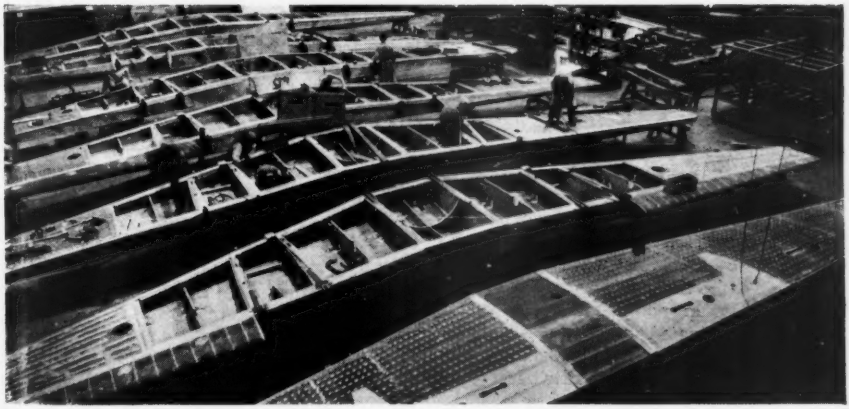




(Above) Assembly shop for fuselages of the Mosquito. The fuselage is dropped on to the centre section of the wing.

(Left) A wing in its vertical jig with clamps round the formers during the glueing process.

(Below) The underside of wings during construction. The plywood underskin is added at this stage.



and laminated spruce flanges. The front spar has three laminations on top and 11 at the bottom. The rear spar has three laminations at the top but only nine at the bottom. The skin passes right across the top and bottom of the spars and is of double thickness on top with spanwise spruce stringers sandwiched between two diagonal layers of ply.

A false leading edge is attached to the front spar and is of conventional built-up construction. The whole of the wing is screwed, glued and pinned and then covered with fabric on top of the ply.

Fuselage

Mosquito fuselages are built in two halves on two half-jigs, the split being along the top and bottom from nose to tail. The two halves for each aeroplane are built at the same time, so that temperature variations affect both halves equally. They stay together throughout the whole process of assembly until they are finally joined. They are not interchangeable.

The fuselage has a sandwich skin made of an outer layer of ply, a centre of balsa wood and an inner skin of plywood again. At the points where the bulkheads are attached the balsa core is omitted and a spruce ring substituted. The skin varies in thickness from 1.5 millimetres to 3.0 millimetres.

There are seven bulkheads in all from nose to tail. Each is built up of two plywood skins kept apart by spruce blocks.

Wherever the skin is most stressed the plywood skin is wrapped on diagonally. Where strength is not so important it is put on straight so as to use less wood. No attachments are made directly to the skin. Instead, a hole is drilled from the inside through the ply into the balsa and a moulded synthetic resin plug with a ply flange is set into the hole and glued in place. The flange of the "top hat" is glued to the skin and the loads are transmitted through this when a screw is threaded into the moulding.

The pick-up points for the wing are made of laminated spruce glued to spruce inserts in the skin and affording a very large bearing area for distributing the loads.

All the equipment, such as electric leads, oxygen bottles, etc., are installed before the two halves are joined. The port and starboard segments of the fuselage are scarfed together with Vee notches, a plywood strip is placed over the joint inside and a ply insert outside. Clamps are put round the fuselage while the joint sets hard. When the two halves are assembled the whole is covered with fabric and doped.

Cabin Heating

Stub radiators in the wing roots make possible a fine degree of cabin heating without extra weight. Cabin heating is an important psychological point in operations and the Mosquito is beautifully warm in flight. One wonders how far the resin-bonded wooden fuselage with sandwich skin of balsa interlayer forms an insulator against loss of internally produced heat or against ingress of cold air at high altitudes. This should prove an interesting problem in the post-war development of air transport.

Rapidity of Production

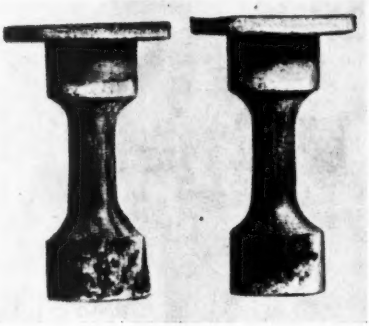
Not only is the Mosquito the fastest aeroplane in service, but it also holds the record for progress from initial drawings to active operation during the war. Only 22 months elapsed between the date when the first drawing was made and the Mosquito's first operation against the enemy. To-day its production is the most widely dispersed of any operational aeroplane, both in England where it is being assembled in several depots and built by more than 400 sub-contractors, and also in Canada.

The extraordinary performance of the D.H. Mosquito and its rapid progress from design to production reflect the greatest credit on the foresight, skill and initiative of the de Havilland design team. Led by Captain Geoffrey de Havilland the executive team responsible for the Mosquito comprises Mr. C. C. Walker (Chief Engineer and Founder-Director); Mr. R. E. Bishop (Chief Designer), and Mr. R. M. Clarkson (Assistant Chief Engineer).

Structure and Breaking Strength of Plastic Mouldings*

Presenting a Broad Survey by a Continental Technologist of Fundamental Factors Affecting the Production of Representative Test Pieces Designed for Investigation of the Mechanical Properties of Mouldings in Thermosetting Resins

Fig. 1 (below).—Present form of tensile test pieces (according to Grimm) for plastic mouldings. It will be observed that, in spite of the provision of ample radii between the working length and gripping ends of these specimens, complete structural homogeneity in the gauge length has not been fully attained.



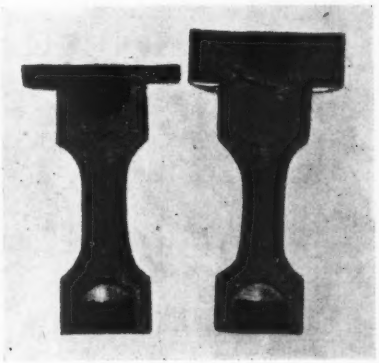


Fig. 2 (above).—Specimen test pieces showing pronounced fissuring within the body of the expanded ends. This is probably caused by the excessive quantity of moulding powder and the time taken to fill the upper portion and extension of the die cavity.

ACCURATE measurement of the tensile strength of moulded plastics is fraught with certain notable difficulties. As opposed, for example, to the determination of bend strength, which requires, say, merely a rod of perfectly uniform rectangular cross-section, a tensile test piece must be thickened at each end in order to take the stresses imposed when fixing in the clamps.

The author has previously shown that the shape of the tensile test-piece for moulded plastics considerably affects the results obtained. If a test-piece of the form commonly used for metals be employed, results vary to such an extent that any possible variation in the intrinsic strength of the material becomes difficult to decide upon.

Later researches by Frischmuth demonstrate conclusively, however, that by the use of improved test-piece shapes and closer control on moulding conditions, tensile strength values can be obtained with no greater variation range than those found, for example, in the case of steel.

The following discussion is concerned with the possible influence of different variables on the structure and strength of the moulding. In so far as the tensile

* G. O. Grimm, "Schweizer Archiv," 1943/9/55.

strength is to be determined purely as an inherent property of the material itself, it is essential to eliminate, during preparation of the specimen, all those factors which will unfavourably influence the uniformity of the moulded and cured material.

The only given values upon which any assumptions may be based are the type of moulding powder used and the method of making the moulding. Moulding temperature, pressure, duration of pressing, shape of the test-piece and the speed with which the moulding powder is given its final form, are all capable of variation within very wide limits. A sound structure can be obtained only if each of these factors and others be carefully balanced one with the other.

In the research to be described such factors were independently varied within broad limits in order to determine how each affected the structure and modified the strength of the moulding.

The mere fact that since research first began into this question the accepted shape of the test-piece has already been altered twice, shows how pronounced is the effect of test-piece form on mechanical test results. Even with a test-piece of the present shape it cannot be claimed that the ideal form has yet been reached. Fig. 1, for example, shows quite distinctly structural differences in the transition zone between the working length and the broadened ends of the test-piece. A cross-section through two specimens, the moulds for which were so heavily charged with moulding powder that hardening actually commenced in the extension of the die cavity, shows how unfavourable upon structure may be too sudden a transition from one section to another (Fig. 2). A test-piece with a smoother transition from the thick to the thin section gives a far more uniform structure.

Fig. 3 (above).—Cross-sections of two moulded tensile test-pieces showing effect on structural homogeneity of variation in die-closing time. Specimen at right, closing time 1 sec.; specimen at left, closing time 30 secs. Fig. 4 (right).—Test-pieces showing increasing structural heterogeneity with increasing moulding temperature: from right to left, moulding temperatures were, respectively, 120, 140, 160 and 170 deg. C.

Fig. 3 shows the effect of varying the time of closing of the die upon the flow of the moulding powder in the die cavity; all other conditions are equal. The specimen at the right was prepared with a closing time of one second, whilst that at the left was prepared with a closing time of 30 seconds.

For each optimum curing temperature there exists an optimum pressing time, departures from which in either direction causes unfavourable alterations in the

structure. Alteration of die temperature affects speed of hardening and the flow characteristics of the moulding powder in the die (Fig. 4). At low temperatures (120 degrees C.), flow is sluggish, but, at the same time, the hardening process is, in proportion, even slower, therefore, an opportunity is presented for adequate filling of the die cavity by the moulding powder, and gases produced by the hardening reaction can readily escape. Flow along the long axis of the test-piece is not too pronounced.

With increasing temperature (120-140 degrees C.), flow of the powder during filling of the die improved and is clearly indicated in the altered appearance of the structure along the long axis of the test-piece. At the highest permissible temperature (170 degrees C.), curing takes place very quickly, and, even though flow is very rapid in the initial stages, yet localized areas of the moulding powder in contact with the heated steel walls of the die have already fully hardened before the die cavity is completely filled. Thus, cold moulding powder flowing into the centre of the die cavity is deflected, hence disturbances are shown in the structure of the finished pressing. Moreover, gases produced by the reaction can escape only in part, and tend to produce porous areas preferably in thicker sections or at transition zones between one section and another.

Finally, definite damage can result to the moulding powder itself at higher temperatures if the duration of pressing be too prolonged. Fillers containing cellulose, for example, may decompose.

Flow phenomena occurring in the moulding powder during pressing depend, however, on still other factors. The condition of the moulding powder immediately before pressing is of vital importance. Tableting, for example, considerably reduces the quantity of air taken into the mould during filling, thus, the danger of porosity is reduced.

The moisture content of moulding powder strongly affects its flow characteristics. If the moisture content be high, the fluidity of the mass is higher than with a lower moisture content.

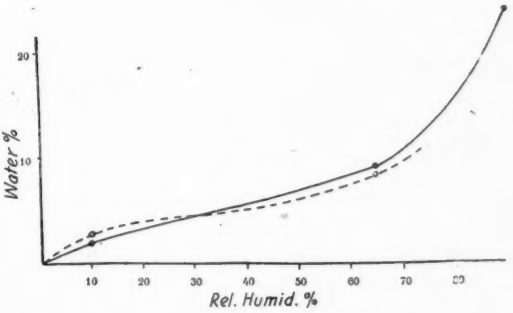


Fig. 5.—Curves for a urea-resin moulding powder (continuous line) and a melamine resin (broken line), showing variation of mechanically bound water content for various relative atmospheric humidities. With the usual relative humidity of 60 per cent., such a water content averages about 10 per cent.; for extreme humidities the mechanically bound water content may rise as high as 20 per cent. of the total weight of the charge.

The water content of the moulding powder corresponds to the humidity of the surrounding air. In Fig. 5 are presented curves for the moisture content of a urea and a melamine resin (both with organic fillers) at various relative atmospheric humidities. Points were plotted after each of the powders had been allowed to attain equilibrium with the atmosphere.

If relative humidity be extremely high, it is possible for the water content of the moulding powder to rise one-fifth of the total weight of the charge. With a normal relative humidity of 60 per cent., the water content of moulding powders averages about 10 per cent.

Apart from moisture present in this way, however, there must also be reckoned with water and other volatile matter, such as ammonia, produced during the curing action, the volume of

foreign matter which must be removed from the moulding powder during pressing is thus of considerable significance.

If hardening takes place too rapidly, removal of the final traces of water vapour, etc., becomes impossible; the gases tend to collect in those parts of the test-piece which are the last to harden off, and give rise to areas of porosity or to fissuring as may be seen in Fig. 6.

The grain size of the moulding powder is equally important.* In Fig. 7 variations in the impact and bend strength of two mouldings are given. The only difference between each specimen was in the grain size of the moulding powder from which they were made.

The optimum grain size for a moulding depends on the section or section variation of the moulding. During the pressing process the "grain boundaries" are, to a great extent, retained; if the individual particles be coarse and present only few contact surfaces through the cross-section of the moulding, then variations in the strength of the moulding from a given powder becomes more pronounced, according to the precise localization of such "grain boundaries." If the grain size of the powder be excessively coarse, then quite apart from such variations as these an overall diminution in the strength of the moulding becomes evident.

In order, then, to ascertain by means of tensile strength the mechanical properties of different plastic mouldings, it is essential to prepare from each of the powders to be tested, test-pieces entirely free from the sources of error referred to. Thus, for every moulding powder must be determined, first, optimum conditions for the preparation of the particular form of test-piece selected. Test-pieces must, therefore, be prepared, in which each of the variables is investigated separately in order that such optimum conditions are finally attained.

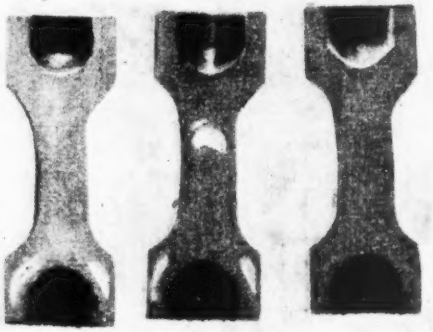


Fig. 6.—Group of three test-pieces prepared (left to right) at decreasing moulding temperatures. In the case of the specimen at the extreme left, two large gas cavities may be seen in the thickened end (bottom) of the moulding. The section reproduced in the centre of the group shows in addition to gas cavities at the thickened end, a large cavity extending almost across the section of the gauge length. The test-piece at the right, moulded at optimum temperature, is free of gas cavitation and porosity and is, moreover, structurally homogeneous.

Fig. 8 gives the results of such a series of tests in which moulding temperature has been selected as the variable, all other conditions being equal. The powder concerned is a urea resin with organic fillers; it will be noticed that the optimum temperature range may be varied very widely. Sections of finished pressings serve to prove any conclusions reached by such tests as these. Each variable may be examined in the same way as the temperature factor is investigated here.

Discussion has so far centred on test-pieces corresponding to mouldings of very simple form. In such cases as these, variation in conditions of moulding become evident at once. The significance of the variables referred to will now be

* Due to the pronounced flow occurring in moulding powders as contrasted with that taking place, say, in metal powders, the danger of "bridging" is not generally to be feared, as even with relatively coarse fillers it is likely that a certain lubricating action takes place. Nevertheless, apart from grain size of the resin component itself in the moulding powder, that of the filler must equally be taken into account. Note in particular the tendency of a filler to segregate at thicker sections in such cases as moulded threads.

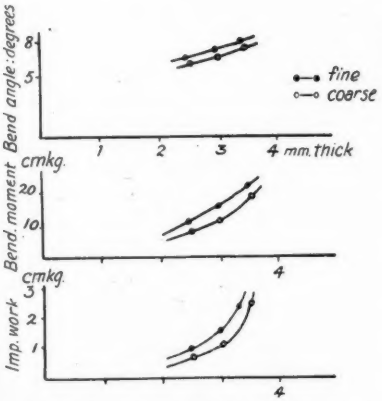


Fig. 7 (above).—Curves for angle of bend, bending moment and impact work required to fracture for two phenolic resin mouldings of identical form and prepared under identical conditions, the only variable being the grain size of the powders employed.

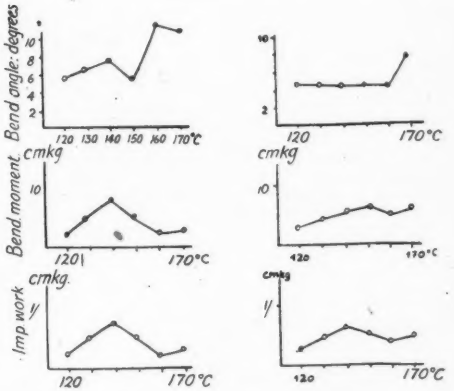


Fig. 8 (right).—Curves for angle of bend, bending moment and impact work required to fracture for two urea mouldings with organic filler. Variation in mechanical properties is expressed as a function of moulding temperature. It will be observed that the optimum temperature range varies over very wide limits.

discussed in relationship to mouldings principally characterized by variation in the ratio of surface to volume.

In Fig. 9 is shown a block of maximum dimension about 100 mm. Fig. 10 shows a sphere of about 100 mm. in dia. If mouldings such as these are to be prepared in practice, considerable skill and experience are required in order to achieve satisfactory results.

In the case of the specimens illustrated in Figs. 9 and 10, this fact was ignored, and moulding conditions were based exactly on those determined as optimum for the test pieces.

The heat conductivity of moulding powders, and of the pressed and cured moulding, is low, so that the exterior layers of the moulding in contact with the die tend to harden whilst curing is still in progress in the centre of the mass. Thus, water, ammonia and so on cannot escape but remain as inclusions, and, according to the amount of such gases present, so will the structure be more or less porous or fissured.

If sufficient heat can be introduced to the centre of the mass from the outside, or, at least, if premature cooling can be avoided, it is quite possible for the heat of reaction in the mass to raise the interior temperature of the moulding above that of the die itself. Fig. 11 gives temperature curves at the surface and at the centre of a moulding weighing about 5½ lb. The interior of such a moulding is clearly subject to uncontrolled factors different from those characterizing the genesis of the exterior; specific gravity, water absorption, strength, etc., will all vary.

In contrast to massive sections, such as the one just cited, thin-walled vessels and casings may readily be given a uniform structure. The surface of such items is very great in comparison to their volume, so that, in spite of the poor heat conductivity of the resin, the entire section very readily attains a uniform temperature.

Only in the case of very large, tall, thin

mouldings will the advantages of this be overshadowed by other phenomena. For example, if a very large die, say, for a radio cabinet, is filled with $\frac{1}{8}$ lb. of moulding powder and closed, part of the powder begins at once to flow on the hot walls of the die; water vapour is evolved, and still

Fig. 9 (above).—Section of moulded block measuring about 100 mm. across its greatest length. As opposed to the test-pieces previously discussed, the volume/surface ratio is considerably altered here and hydrostatic moulding conditions were more difficult to attain. A porous area occurs in the centre of the moulding.

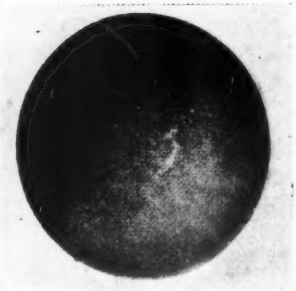


Fig. 10 (left).—Section of moulded sphere showing compact exterior with porous and partially fissured area at the centre of the mass.

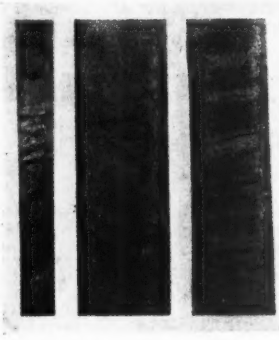
Fig. 11 (below).—Three sections from a thin-sectioned moulding about 200 mm. high, prepared from a rapid-hardening moulding powder. The mass shows marked structural heterogeneity, with clouding, streaking and localized porosity.

unaffected powder becomes "inflated" with gas. Part of the vapour condenses on that portion of the charge which is still cold. Then, in consequence, as this heats up, its flow characteristics are more pronounced than those of the remainder of the charge; so, in spite of the fact that the mould has been filled with a perfectly uniform moulding powder, the charge behaves during the moulding operation as though it were a heterogeneous mixture with varying flow characteristics and hardening properties at different points.

Fig. 11 shows three sections from a casing about 200 mm. high. A rapidly hardening moulding powder was used for this; clouding and porosity are plainly to be seen. The section reproduced in the centre of the group is taken diagonally from the moulding and shows, in addition, how localized, increased flow occurred and gave rise to streaking. Even this extreme case may be taken as illustrating, on a somewhat exaggerated scale, what may occur with test-pieces.

From this research the following conclusions may be drawn:—

1. Where determinations of fundamental mechanical properties of various thermosetting plastic mouldings are to be made, moulding conditions must be strictly controlled. Such conditions vary with every moulding powder, and, before any further steps are undertaken, must be determined for each of such powders. Accurate comparison of mechanical properties is possible only



when all the test-pieces concerned possess perfect structures.

2. On mouldings from any given powder, the range of strength values is of great significance in practice. Such

variations arise as a result of departure from optimum moulding conditions.

3. Test pieces for routine determination in practice do not demand the stringent care necessary for research purposes. On the contrary, limits of variation may be expected and set; by these the moulder can determine whether or not the quality of his product is being maintained at the desired level.

The basis of the testing system for plastic mouldings outlined here by Grimm presents certain interesting analogies with, and contrasts to, those applicable to metal test pieces, more especially those produced by the powder metallurgy technique.

Although not directly referred to in as many words, difficulties caused by the non-hydrostatic reaction of the moulding powder to pressure in complicated die forms gives rise to the principal difficulties experienced, not only in the design and production of test pieces, but also in the design and operation of dies for actual mouldings.

Non-uniformity of pressure in the centre of heavy sections necessitates in the case of moulding powders careful selection of grain size and of the grain size and shape of the fillers. Where these factors are fixed, then for satisfactory results to be achieved, any difficulties arising in moulding must be overcome by modification of pressing time and temperature, or even of mould design.

With metal powders the problem is still further complicated by the wide variation of packing densities experienced due, first, to the greater grain-size range encountered with these materials, and, secondly, because the powders employed are usually very much finer (i.e. 200-400 mesh, say, as opposed to 60-80 mesh, for example, in the case of moulding powders).

The mechanically bound water component of moulding powders finds some slight analogy again in the case of metal powders, although, here, the content is less. Air entrapped in the mass of fine metal powder becomes a much more serious proposition than that held in the body of a relatively coarse moulding powder.

Grimm refers to the retention of the "grain boundaries" of the moulding powder after completion of the pressing and curing processes. A similar phenomenon in the case of metal powders is, broadly, undesirable, and must be countered, as a rule, by sintering at temperatures above the recrystallization point, the duration and temperature of pressing, however, being so controlled that recrystallization, having once occurred, does not continue to the point when coarse growth begins.

It is often stated that the metal powder technologist in his work has borrowed the technique of the plastic moulder. It is suggested that a comparative study of the two techniques might yield information valuable to the practice of both. Perhaps the greatest advantage would be seen in the production of large sintered pressings in metal which have, so far, not been developed to so successful a stage as large plastic mouldings.

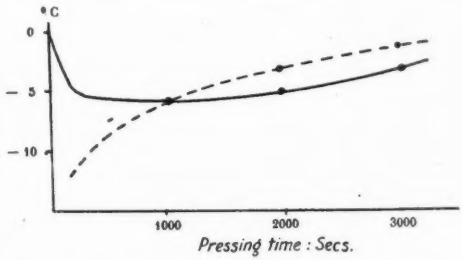


Fig. 12.—Curves for temperature in relationship to pressing time obtained during the moulding of bearing shells. The continuous line represents variations in the temperature of the die wall in contact with the moulding, whilst the broken line shows the course of temperature variation at the interior of the mass.

World's Industry Employs Plastics

AIRCRAFT

Aircraft instruments and small accessories on German aeroplanes are quoted by Boe ("Aero Digest," 1942/41/No. 6) as being 10-15 per cent. lighter than corresponding fittings on American aircraft, whilst armament accessories and engines are 50 per cent. and 9.5 per cent. lighter respectively than on corresponding U.S.A. aircraft. The author traces this weight reduction to a more generous use of plastics on the German aircraft, and makes a plea for further weight reduction in American aeroplanes.

GENERAL ENGINEERING

Protective lacquers for zinc, a metal which, in the plain and alloyed forms, is finding increase use as a substitute for strategic war materials, are dealt with by Baerlocher in "Metall- und-Schmuckwarenfabrikant," 1941/22/352. Nitro-cellulose and phenolic resin lacquers adhere directly to zinc. Alkyd and urea-resin stoving lacquers are preferable in that they possess greater mechanical strength. **Sawing of laminated plastic** requires a saw with rake angle between 5-15 degrees, a minimum clearance angle of 25 degrees, and a minimum lip angle of 55 degrees. A laminated plastic plate 15 mm. thick was cut with a circular saw, the optimum peripheral speed for which was 50 metres per sec., with a feed of 166 mm. per min., blade width being 4 mm. and pitch 6-8. The life of such a tool, possessing a clearance angle of 10 degrees, was more than trebled when the clearance angle was increased to 30 degrees (Ferchland, "Der Betrieb," August, 1942). **Screw machine cams** in a phenolic laminated textile resin are suggested by Kruse of the Western Electric Co. (1943/87/88), where relatively short life together with limited production is envisaged. Steel cams are most satisfactory, but for jobs with a limited production of 10,000-40,000, a cheaper type of cam which may be replaced or scrapped when worn is more economical. The machining of such cams is very simple and rapid. The plastic cams proved successful in trials for runs of 250,000 parts. **Grinding and polishing of tungsten-steel cartridge dies** form the subject of tests recently carried out by the Norton Co. ("Grits and Grinds," 1942/33/144). Various abrasive wheels were tried, the best results being obtained with 100-mesh resinoid-bonded diamond wheels for grinding, and a 500-mesh resinoid-bonded diamond wheel for polishing. Wheel speeds were 2,500 r.p.m. for wheels up to $\frac{1}{2}$ in., and 12,500 r.p.m. for wheels up to $\frac{3}{4}$ in. diameter. Work speed was 300-400 r.p.m. In order that the wheels may cut effectively, index speed should not exceed 0.0002 in. per pass. Table traverse should be slow (20-40 ins. per min.). In one trial, stock removal was 0.016 in. in 20 mins., wheel wear being negligible. Wheels must be lightly dressed with a pumice stick at about 5-min. intervals. The finish-grinding wheel produced a surface finish of 4-5 micro ins. R.M.S. and hand lapping could thus be dispensed with.

ELECTRICAL

Production methods for magnets, consisting of metal powders bonded with synthetic resin, are described by Dehler in " Stahl und Eisen," 1942/62/No. 47. The plastic employed is a phenolic resin or polyvinyl chloride, 6 per cent. of either of which is intimately mixed with a suitably graded metal powder, for example, one consisting of 50 per cent. 1 mm. grain size; 20 per cent. 0.3 mm. grain size and 30 per cent. 0.05 mm. grain size. Compressed at about 6 tons to the inch, the density of the compact reaches nearly 90 per cent. of that of the massive alloy. In the case of a phenolic binder, curing takes place at 180 degrees C. Magnetic components can be made true to size, no machining being necessary, and fine holes can be moulded in. Magnetic properties are equivalent to 80 per cent. of those of the alloy in the massive form. Production of magnetic filaments by extrusion is also made possible. With appropriate binders it is possible to make magnetic pastes or paints which prove useful when additional magnetic fields must be localized at arbitrary points. It will be recalled that Dehler, in " Elektrotech. Z.," 1941/62/601, has previously described **Tromalite magnets** manufactured in this way. Alnico alloys are particularly amenable to treatment by this technique. **Boards for installation of electrical meters** have been made the subject of standards in Germany in order to reduce the numerous sizes at present in use. A moulded board has now been developed to take a meter 5 ins. by 7 ins., together with the necessary fuses, whilst another, 7.25 ins. by 10 ins., takes older and larger types of meter, together with four fuses. **Insulating media for conduit and cable** forms the subject of a comprehensive account by Beck, Cohn and Schneider in " Schweizer Archiv," 1943/9/37. Particular attention is concentrated on corrosion phenomena and destruction of joints resulting from parasitic currents, and a special technique is described for laboratory production of such currents and their direct evaluation both in the laboratory and in practice. The importance of the adhesion of insulating and sealing mantles and paints is stressed in the summary.

MISCELLANEOUS

Organic plastics, their structural characteristics, types, fillers, plasticizers, natural and synthetic rubbers, organic protective coatings, paints, varnishes, enamels, glues, adhesives and insulating materials, are dealt with by Stempel, Stevens, Warner and Fugassi in the fourth edition of " Chemistry of Engineering Materials," compiled by R. B. Leighton and published by McGraw Hill Book Co., 1942. **Safety-glass intermediate layers** boast an extensive patent literature which has been made the subject of a critical review by F. Krczil in " Kolloid. Z.," 1942/98/117; 376. Besides simpler hydrocarbon polymers or halogen compounds, the various polymerized vinyl compounds, such as polyvinyl alcohol, polyvinyl acetate, polyvinyl ether, polyvinyl ketone and polyvinyl esters are examined. Polymethylmethacrylate, acrylic nitrile, copolymerization compounds and cellulose derivations are referred to. **Synthetic resin masses with metal powder fillers** as media for diamond-impregnated grinding wheels, are proposed by J. K. Smit and Sons and P. L. Kuzmick in B.P. 548,536 (abstracted in " Industrial Diamond Review," 1943/3/301). A suitable mixture comprises about 10 per cent. synthetic resin, 30 per cent. 200-mesh copper powder, 30 per cent. 200-mesh tin powder and 25-30 per cent. 240-300-mesh diamond powder. By the incorporation of a suitable plasticizer, the mixture may be rendered suitable for cold pressing.

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

FUEL ECONOMY.—One of the most important methods for the economical generation of power in the chemical, plastics and allied industries requiring a large proportion of heating and process steam is the use of the steam turbine, either pass-out or back-pressure, according to the conditions, and if necessary of very small size, less than 100 h.p. and even down to 20 h.p.

The advantages of the turbine are, of course, more or less well known, and in general a high-speed rotor is far superior for power generation to a relatively slow-speed reciprocating piston, especially as regards very small size and weight per unit power output, higher thermal efficiency, smooth turning motion, absence of noise and vibration, and easy governing to fine limits. Design and workmanship to-day has also reached such a stage of efficiency that a turbine is just as reliable as a slow-speed reciprocating engine.

In this connection much interest attaches to the work of Hick, Hargreaves and Co., Ltd., Bolton, who have an extensive experience in the manufacture of impulse industrial steam turbines of all types and sizes from say, 20 h.p. to 4,000 h.p. Naturally, they have specialized in modernizing factory drive and the substitution of main engines by turbines, using the same foundations and existing rope drive with the addition of electrical generators for lighting and driving part of the machinery.

An outstanding advantage of the steam turbine is the ease with which it operates under pass-out or back-pressure conditions, supplying process steam at any desired low pressure, resulting in a great economy as compared with a condensing steam engine or turbine which loses 50-60 per cent. of the heat of the coal in the cooling water, or the use of live steam for process work from a separate low-pressure boiler plant.

The above firm has specialized particularly on this development, using a turbine not only for main-rope driving and the generation of electricity but also supplying by either pass-out or back-pressure methods the heating and process steam required. As a result the saving obtained is very great, often 25-30 per cent. of the coal bill, and sometimes more, depending upon the ratio between the amounts of steam used for power generation and for heating and process work. A typical example is an establishment working 70 hours a week, with 2,000 h.p. and a consumption of 35,000 lb. of steam per hour at 10 lb. per sq. inch for process work. With a steam pressure of 175 lb., 500 degrees F. superheat, a condensing steam engine with reasonably good vacuum would want 24,000 lb. of steam per hour. At 7 lb. water per lb. of coal this is 108 tons of coal per week. For providing the heating steam also another 140 tons of coal per week would be required, making a total coal bill of 248 tons a week. If, however, a pass-out turbine were installed with steam at 180 lb. and 525 degrees as before, discharging at 10 lb. per sq. inch pressure, all the 35,000 lb. of process steam per hour would be provided, and the total consumption of coal would be only 156 tons per week as compared with 248 tons, that is a saving of 92 tons of coal a week or 37 per cent. saving in the coal bill.

CAMBRIDGE VOLTAMOSCOPE.—The Cambridge Instrument Co., Ltd., has forwarded us details of their new voltamoscope for electro-chemical analysis employing the Heyrovsky dropping mercury electrode.

The Voltamoscope performs the same functions as a polarograph but it is non-recording. It works in conjunction with the same electrodes and the chemical technique is identical, but instead of producing photographic records the voltage and current are read by the operator and plotted on squared paper. Many simple chemical determinations can be done by reading the currents corresponding to two known voltages and finding the difference between them. Apart from the different way of obtaining the results, all the methods relating to the polarograph can be applied to the voltamoscope.

The instrument consists of a polished wood case with a sloping panel at the front carrying all the necessary control knobs and, on the top of the case, a Cambridge spot galvanometer for measuring the

current. Connections from the back of the case are made to an accumulator and to the electrodes. On the panel a large central potentiometer slide-wire controls the voltage applied to the electrodes. To adjust the current through the potentiometer there is a milliammeter and a rheostat. The sensitivity of the galvanometer can be changed over a wide range by means of a sensitivity switch in the top right-hand corner, while its zero is adjusted by another knob below this. The damping control and counter current device are included in the instrument.

COPYRIGHT MUSIC IN FACTORIES.—As announced in the House of Commons last week, an agreement has been made between the Government and the Performing Right Society by which, for the period of the war, the fees due to composers for the playing of their music in factories, and in canteens and hostels established in connection with them, will be covered by a composite payment by the Government to the Performing Right Society.

MOULDING MACHINERY.—The U.S. War Production Board has revised the plastic moulding machinery allocation order L-159. The amended order exempts fixtures in process of manufacture on March 26, 1943, provided they could be completed and delivered on or before May 1. Small sample moulds producing pieces of 30 grams or less also are exempted.

Order L-159 formerly controlled allocation of new and used plastics moulding machinery and fixtures. Used fixtures for plastics moulding machinery are eliminated from control in the amended order.

CANADIAN PLASTICS.—It is reported from Canada that Mr. Garfield Weston, M.P. for Macclesfield, is interested in the formation of a large concern to manufacture plastics " on a scale unprecedented in Canada." He recently bought Lord Bennett's controlling interests in the E. P. Eddy Company, which manufactures pulp.

PLASTICS AT SOUTHAMPTON.— A meeting of the Southern Section of the Institute of the Plastics Industry will be held on Friday, June 11, at the Polygon Hotel, Southampton, when Dr. Harry Barron will give a lecture on " Agriculture and the Plastics Industry."

PLASTICS IN SCOTLAND.—The Institute of the Plastics Industry has now formed a Scottish section. An interim committee under the chairmanship of Mr. C. Chapman has been elected and it was decided to hold meetings in Edinburgh and Glasgow so that both East and West Scotland interests may be served.

At the same meeting Mr. T. L. Birrell, chairman of the Institute, delivered an address on " Some General Aspects of the Plastics Industry."

PLASTICS, AIRCRAFT AND AUTOMOBILES.—On May 11, Mr. M. D. Curwen, Editor of " Plastics," gave a talk on plastics at the Royal Aeronautical Society, to a combined meeting of the graduates of the Institution of Automobile Engineers and the Royal Aeronautical Society. A good time was had by one, and, so it is said, by all.

NEW COMPANIES

BURLAM ASSOCIATED PLASTICS, LTD. (380,691).—Private company. Registered May 20. Capital £6,000 in 6,000 shares of £1 each. Objects: To carry out research work for ascertaining suitable kinds of, and procuring and developing substitutes for, building materials, and for wood, stone, brick, metals and metal goods; coach, lorry and vehicle bodies; fabricated goods, leather, leather cloth, linings, cottons, cloths, baizes and wool, etc.

Co-operation— between User and Moulder

Being a Consideration of Some of the Chief Ways in which Co-operation between User and Moulding Manufacturer is Desirable to Assist the Production of Mouldings having Precision Size and Shape Characteristics

By W. M. HALLIDAY

RECENT years have seen a steady yet substantial development throughout the plastic moulding industry towards the manufacture of precision mouldings to closer and finer degrees of dimensional accuracy and uniformity.

So much progress has already been made along these lines, that the precision moulding has won and maintains a distinctive position in manifold applications hitherto fulfilled by machined metal components employed in numerous branches of the engineering industry.

But what is not fully realized, especially amongst users of mouldings as against purely manufacturers, is that the moulding component possessing close dimensional accuracy, exact size duplication with other mouldings from same mould, as well as reliable mechanical and physical features, entails almost a special technique of its own.

This is certainly the case in respect of the design, construction, and successful operation of moulds for their manufacture. The development of moulding technique during the past 20 years or so occasioned by the change from mouldings having purely decorative, artistic, and pleasing appearance features, to those having accurate and finely controlled size features, has entailed many new problems and difficulties for the moulding expert.

Co-operation of User

This present article, however, is designed to afford examination of some of the chief requirements which have to be met if satisfactory precision mouldings are to be economically produced to meet the approval of both user and maker. It will mainly be directed towards indicating several useful ways in which essential co-operation can be created between the prospective purchaser and user and the manufacturer of such precision mouldings.

At the outset it should be remembered that in many instances where a moulding has been produced and failed to win the client's approval the reasons are not solely attributable to the moulder.

The writer, throughout a period of years, has examined carefully many such cases to find repeatedly that some blame attaches to the user for the moulder going astray on some aspect of the intended moulding. Very often disappointment and an unsatisfactory component are produced because the moulder at some stage has failed to derive a correct understanding of the user's requirements or wishes, often due to incomplete, vague, or inaccurate details supplied.

Complexity of Mould Making

Most engineers outside the plastics industry, when considering the moulding process which they know employs a very accurate steel mould into which the material is pumped under high pressures, naturally expect precision mouldings as an obvious corollary. What most engineers fail to appreciate, however, is that the economic production of mouldings having such characteristics is not simply and solely a matter of correct

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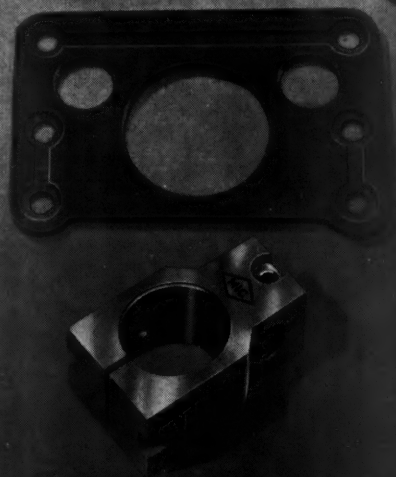

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design and mould construction, or experienced moulding practice.

Many factors enter into the solution of this complex problem, and it is hoped to point out several important ones in the ensuing lines in the hope that some guidance will be offered to would-be users of moulded components of this type.

The Development of Moulding

For those not intimately connected with the plastics industry and its processes, it will be advisable to consider just how a plastic moulding is developed.

Carrying such analysis right back to the originating source, that is the designer or tool engineer of the prospective user, we find that the general configuration, dimensional, and size features are arrived at either by means of making models for actual tests on particular jobs, or by purely theoretical means by laying out on the drawing board and by calculation.

When a decision has been reached upon the best shape, necessary sizes, and tolerances permissible, a similar decision has to be made in respect of the particular type or brand of material to be employed. This, of course, is the stage at which consultations are usually sought with the moulding manufacturer or powder supplier, to obtain expert advice on the most suitable material for the application.

With these questions satisfactorily answered, the scheme is then passed to the purchasing department to secure quotations of the probable cost so that the financial aspects of the job may be weighed up by the user. Thus on the originator's side the idea passes through several channels, such as designer, tool engineer, drawing office, purchasing department, etc. When the project reaches the moulder's end the estimating department in conjunction with the drawing office or design department take up the idea. Consultation will be made with the tool-making section seeking advice on design and construction of mould and the precise manufacturing operations.

Then some consideration must be given by the chemist on the question of powders, colours, flow, etc., and finally the costing department will be called in to assist the estimator to arrive at the most profitable charge acceptable both to the user and manufacturer.

From this brief sketch it will be apparent that a project for a moulding, however simple, must pass through the hands of a large number of vitally interested persons. The originating engineer usually knows exactly what he needs to fulfil his specific requirements. But by the nature of things, since he usually is a specialist in his own particular line, his knowledge of the intricacies and exact production methods of the plastic process of moulding is apt to be scanty and confined to an understanding of its bare outlines only.

Consequently, as will no doubt be readily appreciated, misconceptions, distortion of facts, definite errors in respect of dimensions, uses and requirements very often arise right at the beginning of the planning of a precision moulding. Investigation has indeed revealed this to be true, and it has been noted to be specially so in the case of the precision moulding where a number of very accurate dimensions have to be maintained within close degrees of accuracy, and which must also possess closely controlled physical, mechanical or electrical properties. In such instances the dangers of misunderstanding arising are greatly increased because of the added complexity of moulding design involved.

Costly Results of Lack of Co-operation

Now it is obvious that in those circumstances where the degree of co-operation and understanding between intended user and the manufacturer is meagre, indirect, or vague, the expected outcome must be unsatisfactory mouldings, involving additional expense whilst moulds are rectified, altered, or adapted, failure to meet promised delivery dates, and general worry and disappointment to all concerned.

In cases such as these where precise information has been lacking at the initial stages, or where the moulder unwittingly has failed to grasp aright the instructions

given, his only course is to follow lines of his usual moulding practice, working to his customary dimensional tolerances, and generally supplying a good sound moulding relative to the information given to, or assimilated, by him.

The User's Specification

Means must then be adopted (and it is suggested the moulding manufacturer is the one most fitted to originate this endeavour), whereby closer co-operation is created between the interested parties, and for ensuring the provision of all necessary working and designing information which the moulder should have.

Since it is clear that some blame should attach in many cases to the user, for his failure to submit all the relevant information for the guidance of the moulder, and thereby he is the unwitting creator of misconceptions, etc., likely to cause trouble later, it is suggested that upon receipt of a first inquiry the moulder should take immediate steps to obtain essential information in the following manner, which has proved very helpful.

From the moulder's angle it is of primary importance that the user state in detailed terms the exact use or uses, and its method of functioning which the desired moulding is required to perform.

Also he should state in equally precise terms the properties required of the finished moulding, covering such points as the following brief list of requirements:—

(a) Type or grade of powder material.
(b) Physical properties.
(c) Electrical properties.
(d) Mechanical characteristics.
(e) Important dimensions and size tolerances.
(f) Quality of finish.
(g) Appearance.
(h) Quantities.

In order to assist in securing these details it will be advisable for the moulder to furnish a memorandum covering all these points, set out in the style of a questionnaire for convenience.

When the user has completed this specification it should be returned, together with any samples or drawings. These together then will furnish all the essential working instructions sufficient for the production of the moulds and mouldings.

Of course, it may well be that in endeavouring to complete such a specification the client may have some difficulty due to his lack of knowledge of the industry or processes. As, for example, the determination of the correct type of material. Usually application to the moulder will have to be made on this point, but it is pointed out the latter will be better placed for giving a reliable answer if he is in possession of all other relevant particulars about the matter.

Thus in this way it is emphasized a completed specification along the lines just suggested will enable the initiatory stages of moulding development to be conducted with full confidence, speed, and absence of prolonged correspondence, guesswork, or misconceptions.

The Moulded Drawing

Another very important way in which a user can assist and clarify the work of the moulder is to ensure that any drawings submitted for the latter's consideration are correct and reliable in every particular, and also that the drawing is laid out in such a manner as to render simple and rapid its correct assimilation by others, whom it should be remembered incidentally, may not be as skilful in finding their way about a blueprint as the draughtsman who made it.

The moulding drawing in fact is one of the most important links which can be formed between the user and moulder, and it is plainly to the user's advantage to ensure it is as sound as possible in every particular. Several important points arise when considering the features which a good drawing should have, and it will offer some guide if a few are listed.

(1) It should present a true and adequate picture of the part as well as all instructions being clearly, legibly and accurately shown.

(2) All essential or vital dimensions should be prominently indicated as such,

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in such a manner as to obviate any need for subsequent calculations to be made by the designer.

(3) Tolerances should be clearly indicated according to a well-understood system, which preferably should be specified on the drawing itself, or in the specification.

(4) When dimensioning such drawings the user should always bear in mind the methods of mould manufacture now widely employed. These are usually by precision milling, or by the precision jig boring machine. All important dimensions such as for disposition of cavities, dowels, sprue, ejectors, etc., should be related definitely to a stipulated datum line outside external dimensions of mould block, or coincident with same. This will enable setting-up of mould blocks and their machining generally to be performed with greater ease, speed and sureness as the slide positioning and adjustment of such machines is specially adapted to datum line dimensioning.

(5) The drawing should also bear the specification number or symbol of the type of material, and instruction should also be given as to colour, grade and any special tests or requirements desired in the finished moulding to meet unusual or special service needs. Any departure from usual testing standards in respect of any of its properties should be plainly revealed on the drawing. Unless this is done, by the way, the moulder may inevitably be placed at some disadvantage in correctly judging the type of material to employ or exactly which treatment to perform.

(6) In cases where ensuing machining operations have to be performed on the moulding when it reaches the user's works, this should be very plainly marked on the drawing if it is not practicable to omit such references altogether. Thus the moulder will know exactly which information concerns him and which to disregard. It is a good plan in such instances to ring round such dimensions and also to add the indicating term " Customer's Use Only."

The Sample Moulding

In many instances the client submits a sample of the required moulding sometimes in addition to a drawing, but often to substitute the latter, and in the latter event it means that the moulder has to arrive at the final precise configuration, dimensions, etc., solely by his reference to such a sample. On the face of it this appears simple and indeed it may be easier than working from a drawing alone, but obviously in such cases it is essential that the sample be accurate, in fact an exact duplication of moulding required. Unfortunately this is often not the case for the following reasons:—

(a) Obviously, the user cannot make a proper moulding for his sample, and therefore it must be machined. Thus large areas of its surface may be machined to more or less fine limits which on the actual moulding will not be necessary. Most mouldings are akin to metal castings in this particular that a large proportion of their surface area is unimportant as regards dimensional accuracy, the aim being smoothness, polish, regularity and pleasing appearance.

With the submission, then, of any sample some further guidance must be given the moulder on this point, otherwise a too costly mould may be fashioned and a good deal of unnecessary labour, money and time incurred.

(b) If possible, all mating or associated components should be supplied so as to indicate exactly the relationship moulding bears to same. If this is done the moulding engineer derives a clearer picture of the component he is to make, and in addition may be able to suggest very useful modifications.

In both the moulding drawing and the sample accuracy of the important portions should be aimed at, and such information should be presented in the simplest manner possible.

Duplication and Reproducibility of Mouldings

Usually in a precision moulding another very important feature required is that of exact interchangeability and duplication

of components. The limits of permissible variation in the nature of things must be kept very small indeed. To ensure this entails very careful inspection and gauging of each component.

The main outlines of the moulding process are now fairly well known in practically all engineering circles, and thus only a little reflection is required to understand why in the case of the precision moulding minutely exact duplication of sizes is not uniformly achieved.

Difficulties in Moulding Technique

Necessities of production require that a finished moulding be withdrawn from the mould whilst still in a hot state, then being placed on a cooling bench or table to allow it to cool gradually to room temperature.

In the case of thick-sectioned mouldings it may well be that the skin only is solidified at the instant of ejection with the bulk of the internal composition still in a plastic condition. Thus unequal cooling rates are set up, resulting in warpage, distortion and slight variation in sizes, and departure from precise formation and size of mould cavity.

Then, again, a small amount of time must necessarily elapse before a moulding can be removed from the moulds, and, unfortunately, the moulder is not able to guarantee that this time be the same for every "shot," and, because of this failure, is unable to ensure that each moulding is ejected at the same temperature as its predecessor. This, again, will result in unequal cooling, with variations in amount of shrinkage and the finished sizes of moulding. Furthermore, repeated production tends to increase unduly the heat of the moulds, and occasionally they have to shut down for a short period to allow them to be cooled to normal working temperature. This, again, entails a gradual increase in temperature at which mouldings leave the mould, in turn, again causing unequal shrinkage and size variations.

Then occasionally a moulding will tend to stick in cavity or hang on ejectors, or drag over cores, these, again, causing some slight delay in securing withdrawal of moulding from mould, and such parts nearly always exhibit appreciable departures from stipulated tolerances reached by previous mouldings.

These points are mentioned in order to illustrate that excessive mould temperature, delay in ejection, dragging action of cores, sticking of mouldings in cavities, etc., all of which are liable to occur frequently, combine to cause departures from exact duplication of parts and formation of mouldings which are a replica within close size limits of the mould cavities.

Need for Gauging

Admitting, then, these seemingly unavoidable, slight variations which are likely to present some trouble, in the case of precision mouldings, some amount of careful inspection, testing and gauging must be carried out on each piece after cooling off to normal temperature.

Now the degree to which such gauging is necessary and the extent to which it should be performed are best decided upon by the customer. In the majority of cases he alone knows all the requirements called for and, accordingly, is best able to decide what amount of gauging, the best points for gauging, as well as permissible tolerances.

It is also far preferable for the user to furnish all such checking gauges, and this is widely adopted. From the writer's experience, he has found this to be another source of worry and misunderstanding between client and moulder, hence it is desirable that some guiding notes be appended.

In the provision of such gauges, the user should endeavour to make them of as simple a design, construction and method of using as possible. They should be foolproof in action and adequately durable to withstand use throughout whole batch of mouldings ordered. It should also be remembered that usually unskilled or semi-skilled labour is available for such operations, hence they should be of robust but extremely simple form.

It also needs to be borne in mind that one of the prime advantages of a moulding is to effect elimination of a proportion of machine manufacture, and so effect a reduction in costs. If care is not exercised, complicated and expensive gauges may be fashioned which may more than offset the gains derived from using a moulding at all. Thus all methods of gauging involving a protracted or elaborate operation should be avoided.

Gauge Registration

Some attention should also be devoted by the gauge designer to the wisest selection of the correct spots on the moulding from which to register the gauge.

That this is not always easy is illustrated by the fact that every moulding possesses some degree of flash formed on its surface coincident with the parting line of the mould blocks. This has to be removed and cannot usually be effected without some flattening of the edge from which flash projects. Thus it is essential that gauging be avoided from such edges otherwise false sizes will result.

Again, slender sections of the moulding should not be selected as points from which to register the gauge. If snap or common gap gauges are employed for checking, say, a diameter, it is easily possible to distort a slim moulding section by the act of pressing over the gauge.

Similarly with regard to plug gauges employed for testing bores and holes. These should be as light as possible and the entering edges free from sharp corners so that when gauge is presented to mouth of hole no shearing, wedging, or locking action may arise, which may cause a slight amount of material to be scraped off hole, making some bell-mouthed, taper, or oversize.

It should be understood that wherever possible such gauges should be of the "Go" and "Not Go" type, so that the user is enabled to test a part with reliability, as the size must fall between two limits, instead of one only, as happens with a simple "Go" gauge. In the latter case much depends upon the degree of skill and "feel" of the user.

Conclusion

From what has already been written it will be realized that the prospective user of precision mouldings has an important part to play in the production of such parts, and is under obligation to use every endeavour to furnish reliable information, drawings, and working instructions which will embrace all those points upon which the moulding manufacturer needs guidance.

By giving willing co-operation along these lines just suggested, he will make it possible for the moulder to meet exactly his requirements, and thus will stand a good chance of avoiding worry, delay, unsatisfactory products, disappointments and expense.

In another article the writer will endeavour to outline some of the obligations of the moulder as the supplier of precision mouldings, and will attempt to offer suggestions for overcoming some of his special difficulties in fashioning an article to the complete satisfaction of his client.

Metals

The current issue of "Endeavour" should be read if only for one of a number of excellent papers. Sir Laurence Bragg has contributed one on "Metals" which, for lucidity of reading and beauty of illustration, has never been excelled. While this subject is not generally considered "up our street," we assure our readers that this exposition of it is very much so, since it unfolds a picture of the structure of metals compared with organic compounds in general and plastics in particular.

He tells us why metals are strong and describes the experience of handling a rod of metal in the form of a single perfect crystal as being as weak as Plasticine, for it can be stretched by the fingers with hardly any resistance. Directly it is distorted and thoroughly maltreated, it assumes the well-known rigid strong character.

The story is illustrated by beautiful photographs of "rafts" of tiny soap bubbles in behaviour analogous to metal structures. By the introduction of new bubbles of larger or smaller size into the "rafts," he shows how, similarly, small impurities affect the mechanical properties of metals.

Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

XIX.—Electrolytic Aspects of High Polymeric Systems

AS has already been outlined earlier in Section XIII, the molecules of material bodies, according to the electronic theory, are regarded not as a whole continuous mass, but as definite systems of the discrete concentrated corpuscles carrying electric positive and negative charges and separated by physical space, or the ether, whose fundamental nature is completely devoid of properties associated with matter.

The phenomenon of the "electric charge" is thus the exciting cause of a peculiar state of space in its neighbourhood, viz., the electrical state, and the region where the manifestation of the force from this source takes place, constitutes the electric field. Under the action of attractive forces between positive and negative charges, the lighter components, the electrons, which form the elementary negative charges, execute a cyclic orbital motion around more heavy positively charged nuclei, and the motion of electric charges gives rise to the phenomenon of the electric current. All matter with respect to the electric current may broadly be divided into two main groups: (a) such substances that are capable of maintaining the electric state for an indefinite time within them, designated as dielectrics or insulators, and (b) the materials, known as conductors, in which the charge is propagated almost instantaneously over the whole body, whose electric field thus dies away as quickly, unless it is being continually added to by any suitable means of electrification.

The first group comprises such materials as mica, quartz, amber and other natural or synthetic resins, rubber, silk, paraffin, oils, vapours and gases in the ordinary state, the space devoid of matter (vacuum), etc.; the second group includes all metals, graphite, charcoal, solutions of acids and salts, incandescent gases, etc. The group of substances occupying an intermediate position between the above two, the so-called semi-conductors, is exemplified by many inorganic minerals, wood, paper, linen, leather and the like.

The Properties of the Electric Current

Since a direct observation of an electric current is, clearly, impossible, its presence in a conducting material can only be detected by the phenomena and the effects which accompany the passage of electricity through a given medium. The range of these phenomena is very diverse, the following being the most fundamental.

Every transfer of charges, constituting an electric current, whether in a solid, liquid or gaseous conducting medium, gives rise to a magnetic field around the conductor, and, generally, is accompanied also by the development of heat. While, however, the moving electric charges are inseparable from the magnetic field, which may be regarded as merely another aspect of electric lines in motion, the flow of an electric current free from the thermal effect is, under special conditions, quite possible, as for example, in the case of super-conductivity, when the current induced in the circuits at extremely low temperatures (e.g., about 4 degrees absolute) apparently encounters no resistance at all, and continues to flow indefinitely without evolution of heat.

Finally, the passage of an electric current through certain liquids (e.g., water solution of acids or salts), possessing the conducting property, evolves chemical changes in the latter, accompanied by the liberation at the electrodes of the component parts of the solution, the whole process being known as electrolysis.

Molecular Processes in Dielectrics

The fundamental feature distinguishing dielectrics from substances possessing the power of the electrical conduction (viz., metals, electrolytes, etc.) resides in the fact that, while in conductors the electrons are easily detachable from the molecules, and, passing from the orbits of one molecule to those of another, are rendered highly mobile, with dielectrics, on the contrary, the electrons can be split off from the molecules only with an extreme difficulty and are thus denied such a degree of mobility.

In contradistinction to conductors, where the action of the electric field gives rise to motion of the charges in the direction of the field (actually, the stream of electrons moves in the direction opposite to the intensity of the electric field), no such a continuous movement of charges occurs in a dielectric, but the latter is said to be polarized.

The molecules with respect to their structure may be of two kinds. In the molecules of one kind the centres of the positive and the negative charges coincide. In the molecules of another kind these centres do not coincide and form dipoles. The dipoles in the neutral state (i.e., in the absence of the electric field) are chaotic, situated in such a manner that all directions of dipole axes are equally probable, and, consequently, they do not create any external field. The polarization of the dielectrics of the first kind in the electric field is manifested as a displacement (or divergence) of the centres of charges under the influence of the field forces. The centres of the positive charges are displaced in the direction of the field, and the centres (of the orbits) of the negative charges in the reverse direction in such a way that the displaced centres of charges, in a certain sense, becoming the poles, form the dipoles.

The polarization of molecules of the second kind is effected by a certain turning of all dipoles under the action of the field. If the dielectric comprises the molecules of one and the other kinds, both types of the polarization may occur simultaneously. As a result of one and another phenomena there arises a secondary field, the direction of which is opposite to that of the external field.

The divergence of the centres of the positive and negative charges in the molecules of the first kind may be considered as proportional to the pressure of the applied external field.

The equivalent electric moment resulting from the turning of the molecules of the second kind in the field direction, as well as the moment obtained by the divergence of the centres of the charges (the poles) in the molecules of the first kind, may be taken as proportional to the intensity of the impressed field.

The resultant moment of the polarized molecules of both kinds may also be regarded as proportional to the pressure of the applied field.

Although the divergence of the dipoles, which is effected in the molecule as a consequence of polarization, is dimensionally very small compared to the molecular size, none the less, owing to polarization, there takes place a definite weakening of the external electric field, since the displaced charges create the reverse field.

Action at a Distance and Action Through a Medium

Let us now consider a uniform field between two plane and parallel plates, on whose surfaces reside the respective electrical charges.

Prior to Faraday the dominant opinion had been that the charges act one upon another at a distance regardless of that medium which intervenes between the charges forming the electric field.

Faraday, on the basis of his investigations, had established that the action of one charge upon another is effected by

means of a medium separating them, and that the force of their interaction depends upon the physical properties of the interposed medium. These far-reaching discoveries of Faraday that the electrical state is carried by the surrounding space and is propagated in it from point to point (on the theory of action through a medium) has been mathematically formulated by Maxwell, and found the complete verification nearly half of a century later in the brilliant experiments of Hertz.

The actual mechanism of interaction of the electric forces between the nuclei and the surrounding electrons, as well as the way of the realization of the electric field in space devoid of matter, still remain obscure. It is generally held that the cosmos and all matter are pervaded by the so-called ether, which possesses the properties of serving as a carrier of the electric and magnetic fields and the seat of the distribution of energy, this hypothetical agency being instrumental for the interaction of the electro-magnetic forces between discrete parts of the space.

Indeed, the electrical excitation of the ether has its end points at the charges; these are the places where the electrical state of the ether originates. The ends of the line of the force have special properties. The negative end is capable of independent existence as an electron, without being necessarily attached to a material body, and is, therefore, observable as pure electrical substance. The positive end, on the contrary, is of material character, or, at least, it is always associated with the mass corresponding to a hydrogen atom. What the nature of the combination is—whether the hydrogen atom or other similar part of an atom is merely bound to the positive charge, or whether the mass of the hydrogen atom represents simply the end of the line of force itself—these are questions which have not yet been answered. The apparently continuous structure of the field is, therefore, built up statistically by the tension and transverse pressure of the lines of force corresponding to the elementary charges, which are always present in enormous numbers, and through which the charges which occur in ordinary experience develop their action.

The notion of the ether with the definite physical properties, the presence of which may be revealed only by indirect observations, on the one hand, and the concept of the discrete nature of the structure of matter (i.e., the discontinuous constitution of the mass of the material body) on the other, often revive the old dispute: whether or not there exist the action at a distance. However, these problems lose any significance in the light of the latest conceptions, which are gaining ground in the modern physics. These views, which are being evolved as a result of the discovery of the dependence of the mass upon the velocity and the observed transformation, under certain circumstances, of the mass of moving electrons into the energy of the electro-magnetic waves, lead to the conclusion that the mass is merely a point of the energy concentration.

Interconnection Between the Electrical and Chemical Phenomena

From our discussion of the electrochemical aspects of high polymers in Sections XIV and XV it must be perfectly clear that the chemical changes of matter are intimately bound up with its electrical structure; therefore, the study of conditions, under which the mutual energy transformations may be turned to practical account, particularly those resulting from the action of the electric current upon chemical substances, is a field of great promise in application to plastics via electrolysis.

The first among the uses of the electrolysis in this direction is, obviously, the electro-deposition of the resinous and other high molecular materials (i.e., the deposition of a surface layer or film of these products) with the view to improving the appearance of the surfaces of objects or to rendering them more resistant to mechanical wear or chemical attack. As was already pointed out in

Section V, the problem of the electrodepositing of plastics coatings did not receive up to now the due attention of the technologists, which it surely deserves, and only a few isolated efforts in this direction are on record, such as the anode process for the production of films from aqueous dispersions of rubber latex, and recently the first endeavour made in the U.S.A. to obtain electrolytically films from lyophobe solutions of synthetic resins. It is of interest to note that the results of even these limited attempts have demonstrated that the potentialities of the plastics electrolysis are very far-reaching, for this technique has the advantage of yielding a deposit of strongly adherent, smooth, compact resinous layer of uniform thickness and texture upon surfaces with very irregular depressions and elevations.

By analogy with electroplating with metals, the process offers many possibilities in galvanoplastics, namely, the electrolytic deposition of the resinoid substances upon the conducting surface for the preparation of plastic reproductions of various objects; non-conducting articles can also be electrolytically coated with resinous compounds by rendering their surface conducting by rubbing with powdered graphite or by other appropriate means (viz., surface impregnation with a conducting medium), the process being, of course, of equal utility for the electrolytic deposition of a suitable metal upon the surface of the plastic objects, as will be expounded subsequently in greater detail.

The scope of the galvanoplastics will become still more apparent if we recall that the total average of continuous current used annually by the world industry for electroplating with metals on the eve of the present war was estimated to be of the order of over 5.10^6 amperes. There is no reason why a comparable development could not be reached in due course by the plastics industry, if the problem is attacked with the seriousness it warrants.

Another operation of importance offered by a similar technique is the treatment of continuous sheeting or other materials through the electrolytic impregnation with the plastic compositions by calling into play the electrophoretic and electro-osmotic phenomena for the manufacture on a large scale of numerous products with novel and superior characteristics.

Electrolytic Conductivity, Electrolytes, Ions, and the Process of Electrolysis

The maintenance of an electric field in a conducting medium necessitates the expenditure of work, the force producing the motion of charges between any two points of circuit in conducting connection is usually referred to as the electromotive force or voltage, the electric pressure at a point relative to the earth, whose electromotive force is taken as zero, is termed the electric potential at the point.

When any two points, which are at different electrical potentials (that is, between which there are electric lines of force) are joined by a conducting path, the electric charges are enabled to follow the tension of the lines of force. As the opposite charges unite, the lines of force vanish, their density decreases and hence also the field strength and the potential difference. Therefore, in order to maintain the original difference of potential, new lines of force must continually be produced, i.e., new charges equivalent to those which have united by the passage through the conductor must constantly be brought to the two points.

From the above it follows that the electric current may be regarded as a stream of electrons flowing between two poles at different potentials; by maintaining one and the same potential difference between the poles we obtain in the conductor a constant continuous or unidirectional electric current, which may conveniently be derived from any suitable sources, such as voltaic or galvanic cells, or primary elements or couples, the secondary or storage or accumulator batteries, dynamos, rectifiers, etc. In contradistinction to the above, when the current strength periodically changes, and the current alters its direction within

certain intervals of time, i.e., in the case of the reversals in its flow, we have an alternating or oscillating current.

Properties of Conductors

The substances possessing the power of conducting an electric current fall into the so-called conductors of the first and of the second kind. The conductors of the first kind are first of all the metals (solid and liquid, such as mercury and alloys) displaying the metallic conductivity, which is effected by the slipping of electrons from one atom of the metal to another, being conditioned by a very feeble linkage of outer or valance electrons with the positive nucleus of the metallic atom. The passage of an electric current through the metal causes no chemical change in it, but is accompanied merely by evolution of heat, the greater the heat the higher the resistance of the metal to electronic motion. A similar conductivity is exhibited by certain other materials, such as coke, graphite, selene. The characteristic distinction of the metallic conductivity is precisely the absence of a chemical change within the conductor.

If a metallic conductor, with the electric current flowing, is cut and its ends fitted with the carbon, platinum or other plates, are dipped (without touching each other) into a liquid (of non-metallic character), it will be found that this liquid either completely bars the passage of the electric current—i.e., functions as an insulator—or allows the transmission of the electric charges and at the same time itself undergoes a chemical change. A liquid capable of transporting electricity is called the conductor of the second kind; the chemical change that takes place within such a medium is usually referred to as electrolysis; the two terminal plates of the metallic conductor led into liquid are electrodes, while the negative electrode, through which the stream of electrons enters the liquid, is the cathode, and the positive electrode is the anode. Thus, the conductor of the second kind is said to possess the electrolytic conductivity that is accompanied by its chemical decomposition—electrolysis.

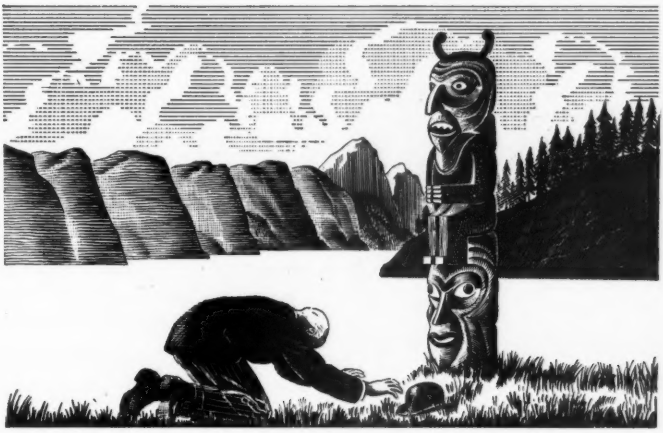
The phenomena of electrolysis have attracted the close attention of chemists for a very long time, and since 1800 their study had commenced in earnest. The classical works in this field are the researches of Faraday, who, in 1832 and subsequent years, was able to provide the precise explanation of the electrolytic phenomena (including the nomenclature) and to embody the results of his comprehensive experiments into the well-known electrolysis laws.

The electroconductivity of the chemically pure water is nearly nil, and it is thus almost perfect dielectric; the salts, acids, alkalies in the cold are also non-conductors, if they contain no water. But aqueous solutions of these three classes of substances—and only these, but not the other bodies—represent the conductors of the second kind, while other water solutions, for instance, those of sugar, are practically entirely non-conducting.

Mechanism of Electrolysis

It is of interest to recall briefly the mechanism of electrolysis, as originally interpreted by Faraday, according to whom the process consists of the following:—The molecule of each electrolyte (by which term Faraday meant all the "bodies which may be decomposed by the electric current"), dissolved in water, is dissociated in solution into the radicals, some of which carry the positive electric charge, the others—the electro-negative charge; the magnitude of these charges is always the same, so that the solution in its entirety is electrically neutral. These electrically charged molecular radicals Faraday called ions, of which the positively charged (released at the cathode) are cations, and the negatively charged (liberated at the anode) are anions.

When we dip into electrolyte the cathodic and anodic plates, each of them will attract to itself an oppositely charged ion: the negative electrode, the cathode, draws the positively charged ions, the



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cations; the positive electrode, the anode, attracts the negatively charged ions, the anions. On reaching the cathode and touching it, the cation takes up from it as many electrons as there has been lost by the corresponding radical of the molecule of the electrolyte in the process of becoming the cation; the cation has now been converted into the radical of the molecule, which is electrically neutral, not capable to exist in the solution or in a free state, as the molecular radicals generally; this radical, consequently, immediately undergoes a chemical change depending on the nature of electrolyte. In a similar fashion, the anion on reaching and touching the anode, dons to the latter all its acquired electrons and becomes an ordinary molecular radical, which is also subject to one or another change.

In electrolysis the number of electrons given away by the cathode is always equal to the number of electrons accepted by the anode: the passage of the electric current through a solution of the electrolytes (now often termed ionogenes or ionformers) is effected solely by the agency of the ions present in solution.

Thus, the mechanism of electrolysis, as visualized by Faraday, consists in the transport of ions, their conversion into the radicals of molecules or the atomic groups, and alterations of the latter; by these changes we are enabled to gain an insight into the constitution of the molecular radicals, and the structure of these radicals, in turn, indicates the composition of ions, which differ from the radical of the molecule by the presence of electric charges, which are absent in the ordinary molecular radicals.

Since the electric current is produced by the motion of electric charges, it can be determined as a quantity of the electric charges passed through a conducting medium in unit of time: $i = \frac{dq}{dt}$, where i is the current, dq – the amount of charges passed through any cross-section of the conductor during an interval dt.

For the quantitative estimation of the electric current may be used either its thermal effects or its interaction with a permanent magnetic field or with another similar current or its electro-chemical action.

In electrolysis (during the electrochemical decomposition) each atom or ion is the carrier of a quite definite electric charge, and, therefore, the quantity Q of a substance deposited at the electrodes is proportional to the current strength and the time of its flow, i.e., $Q = \int dq = \int idt$.

Accordingly, based on the electrochemical action, the international standard of measuring the quantity of electricity, the coulomb, is defined as that amount which deposits 1.118 mgm. of silver at the cathode when passed through a silver coulombmeter, one coulomb per second being the ampere, designating the unit of current strength.

Cataphoresis and Electro-endosmosis

Analogously to the water solutions of crystalloids, hydrosols are electrically perfectly neutral; some of them conduct electric current, the others completely bar it. The electro-conductivity of aqueous colloidal solutions was formerly attributed to the presence of the electrolytes-crystalloids; but the study of the hydrosol containing no electrolytes demonstrated that certain pure hydrosols also possess the power of the electro-conductivity. Thus, just like the crystalloids in the true water solutions, some of the dispersoids in the colloidal solutions may be electrolytes, the others non-conducting; the electrolytes are more frequently the inorganic colloids, non-electrolytes—the organic dispersoids.

During the electrolysis of aqueous solution of electrolyte the ions of the latter are simultaneously moving in solution towards the cathode and anode, and by the products deposited at the respective electrodes one is enabled to judge as to the nature of the ions.

In electrolysis of the hydrosols there has been revealed a phenomenon which at first appeared to be in a different light; under the influence of the electric current the colloidal particles in the electro-con-

ductive sols are moved towards one of electrodes only—the phenomenon of the so-called electrophoresis or cataphoresis, which is particularly noticeable in the case of the pigmented hydrosols by the intensified colouring of sol in the proximity to one of the electrodes. This phenomenon is readily observable with the aid of the ultra-microscope, the velocity of motion being of the same order as the ionic mobility of the crystalloid-electrolyte in the electric field of the identical strength.

Electrolysis of Hydrosols

The electro-conductivity of the pure hydrosols is not very high in comparison with the conductivity of aqueous solutions of electrolytes-crystalloids, but its existence proves that in such a hydrosol must be ions, otherwise there would be no flow of the electric current through the solution; these ions may only be formed from the micelles, which, consequently, shows that in certain cases the latter have the property to be ionized by water. The nature of these ions is definitely indicated by the products released at the electrodes, and testifies to the fact that the electrophoresis is the migration in the hydrosol of a large ion, which was formed from the micelle, but not the transfer of the latter.

Similar phenomena also occur in the course of electrolysis of other hydrosols conducting an electric current: in every case the products liberated at the electrodes display the presence, side by side with a giant cation or anion, of other small anions or cations carrying an electric charge identical with that of the great ion. The degree of the ionization of micelles in hydrosols is, generally, of the same order as the degree of ionization of the molecules of the electrolytes in aqueous solutions of crystalloids, and is the lower, the larger the micellar dimensions.

Thus the experiments show that the micelle of a hydrosol is capable of dissociating into ions, which differ from the ions of an electrolyte-crystalloid merely by their mass—the mass of one of the ions is hundreds and thousands times greater than that of another ion, whereas the mass of the crystalloid ions exhibits no such dimensional contrast between cation and anion. A highly complex and extremely large ion of the micelle Duclaux terms the granule, and the second ions the ordinary or free ions of the micelle, as they are identical with the crystalloid ions. In the electro-contactive hydrosol a micelle is ionized into the granule and the free ions, which under the influence of the electric field are drawn towards different electrodes. The granule is a micelle deprived merely of several atoms, and, as a very complex structure, still possesses the bulk of the atomic mass, of which only a few single atoms part with their valence electrons or acquire some extra electrons. For these reasons it is possible to consider the constitution of the granule as identical with that of the micelle, where, as it was first suggested by von Weimarn, the atoms of chemical elements must be arranged in a certain definite order, i.e., the structure should be of the vectorial type and approach the state of crystallinity.

Having regard to the speed with which, generally, the formation of a micelle occurs there is no ground for assuming that the atoms in the micelle will immediately be distributed in an order corresponding to the maximum stability; it is much more probable that their arrangement will at first be chaotic and haphazard, and only subsequently there will take place the due transfer of the atoms tending to form a more regular pattern—giving rise to the emergence of the micellar structure with crystalline features. Indeed, nearly every hydrosol exhibits the spontaneous variations of its dispersoid, which are sometimes detectable by direct observation, but more frequently manifest themselves through the changes of the physical properties of the hydrosol, such as its electro-conductivity on standing.

If during the electrolysis, the small particles of a substance cannot freely migrate in the liquid towards one of the

electrodes, as, for example, when the latter are separated by a porous membrane, the liquid contained between the electrodes then begins to move in the reverse direction. This is the essence of the phenomenon of the electro-endosmosis, discovered, like that of the cataphoresis, by Professor Reiss at the University of Moscow in 1808.

Hence, if the particles forming the dispersoid phase of a conducting system be held at rest, the oppositely charged fluid is set in motion; thus, for instance, the moisture can be driven out of the damp wood, or any other porous material, when the latter is placed between the two wire gauzes and an electric pressure is applied, thereby furnishing the basis for the process of the electric drying.

The electro-osmotic phenomenon in the electroconductive system (in a hydrosol) is easily observable in the case, when a porous partition is interposed between the electrodes, permitting the diffusion of a liquid, but impeding the passage of granules; the electric current transports the liquid medium through the porous membrane, but the granules are stopped and embedded within the porous body of the diaphragm. This method of the electro-osmosis and that of the cataphoresis may prove to be of great advantage in application to an extensive range of important technological processes, such as total and localized impregnations, coating operations, film-formation, and the like, the development of which, in the author's opinion, will be found of inestimable practical value to the entire plastics industry.

The foregoing electrokinetic processes immediately confront us with the fundamental phenomenon underlying the electrification of matter, which may be stated as follows: When a body is brought into contact with another body composed of a different substance, the two bodies become oppositely electrified. Such a field of the molecular dimensions formed by the inherent electrical forces of the matter on the boundary surfaces is defined as an electrical double layer. It is known from hydrodynamics that when a solid particle moves through a liquid, it generally carries the surrounding "skin" of the liquid along with it. Hence, in consequence of the electrical double layer, the particle is always accompanied by a charged envelope, a factor of the utmost importance in the behaviour of the colloidal systems, affecting the stability of colloidal solutions, coagulation, etc. The conductivity measurements of the electrolyte solutions reveal that their electrical resistance varies in a parallel manner to the viscosity of solvent; this striking fact indicates that during the passage of the electric current the particles of solvent are displaced relatively to one another, i.e., that the ions are enveloped by shells of solvent molecules, which phenomenon is known as solvation, or in the case of water, hydration. The amounts of water transported by the ions can also be measured directly by enclosing the electrodes in appropriate diaphragms. Hence the estimation of the absolute ionic mobilities affords the effectual means for determining the dimensions of the moving complexes. The formation of solvated complexes is to a large extent the governing factor in the solubility of a substance in the liquid medium.

The Structure of Electrical Double Layer

The stability of the colloidal systems has been regarded for a long time as associated with the electric charge of the particles. Whilst, however, in the purely qualitative sense, it is not difficult to understand that the charging of particles increases its stability, whereas the reduction of the charge decreases the stability, from the quantitative point of view the connection between the particle stability and that of the charge and the boundary potential are still not sufficiently elucidated.

Owing to absence of quite clear concepts as to the relationships between the charge and potential in electrical double layer and the role of the charge, the potential and double layer in the impact

of the two particles, in the colloidal chemistry, for instance, the notions of the charge and the potential are sometimes confused.

Conceptions Regarding the Double Layer

The first difficulty in the studying of this problem is the existence of the two ideas with regard to the double layer: (a) in the shape of an areal double layer and (b) as a double layer in space.

Let us consider an electrical double layer on a solid substance in some aqueous solution. Let us suppose that on the surface of the solid body there is, for example, a negative charge $-q$ per one sq. cm., whilst the positive layer of the ions with a charge $+q$ is in the liquid opposite the negative charges.

By using the first notion, we effect the concentration of the positive layer in a certain plane which is very near to the negative charges, whereas, from the standpoint of the spatial double layer, the positive layer is distributed in a definite manner in water under the action of diffusion and electrostatic forces and possesses a finite thickness. The areal double layer is usually called the Helmholtz layer, first formulated in 1879, while the spatial or diffusion variant, of later origin, is known as the layer of Gouy.

The existence of two notions of electrical double layer is bound up with the historical development of the colloidal chemistry. At the present time it may safely be stated that the spatial concept has completely superseded the theory of a plane structure of the double layer; every double layer possesses a certain finite thickness, which cannot be neglected.

A thorough account of the subject contains the works of Gyemant,[267] who treats the distribution of electricity in the double layer with the aid of the Maxwell-Boltzmann statistical laws. Müller,[268] by means of the same mathematical tool, was able to obtain for a slightly curved electrical double layer a certain dependence between the charge of the solid surface, concentration and the boundary potential of the system.

(To be continued.)

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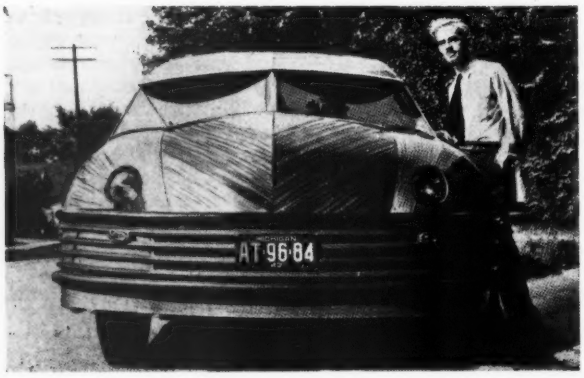

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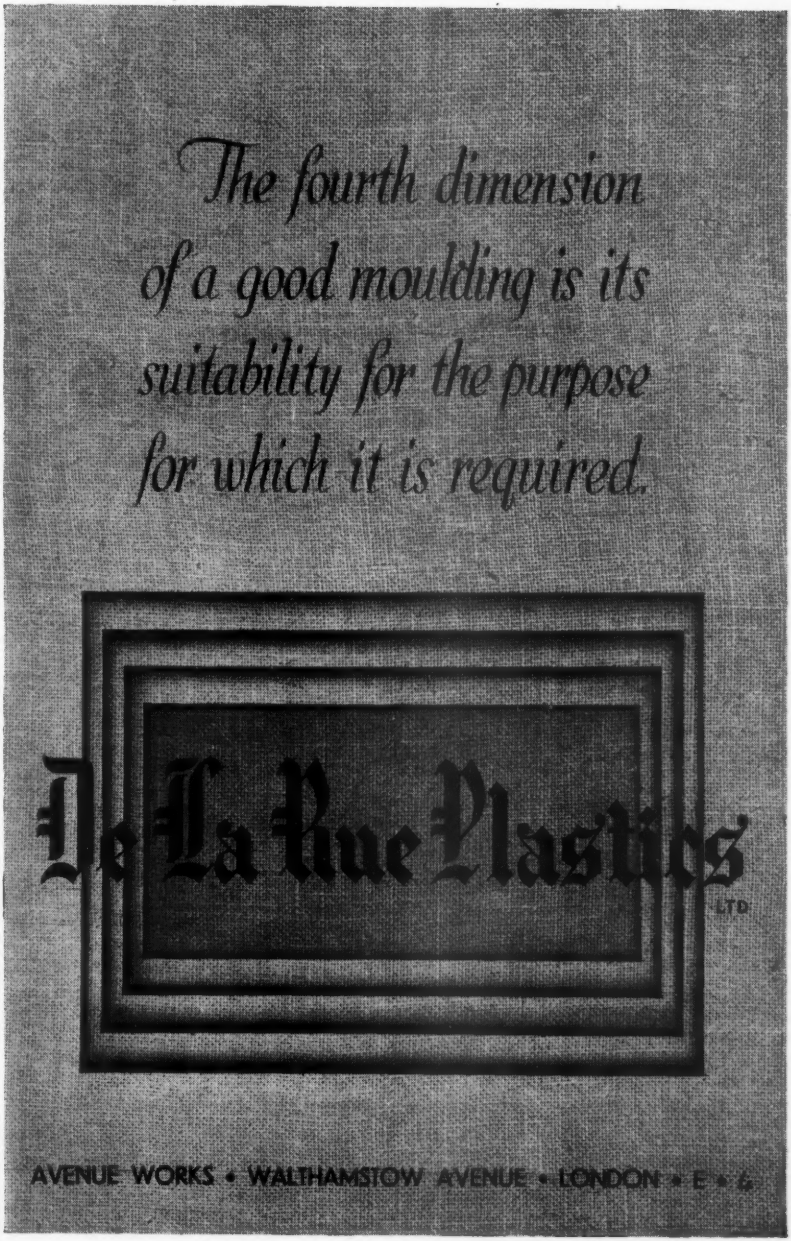
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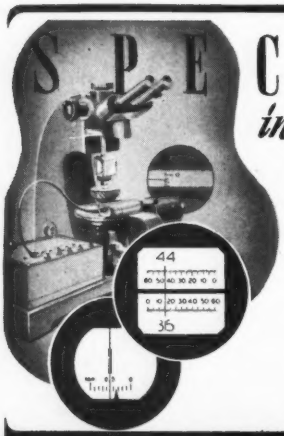

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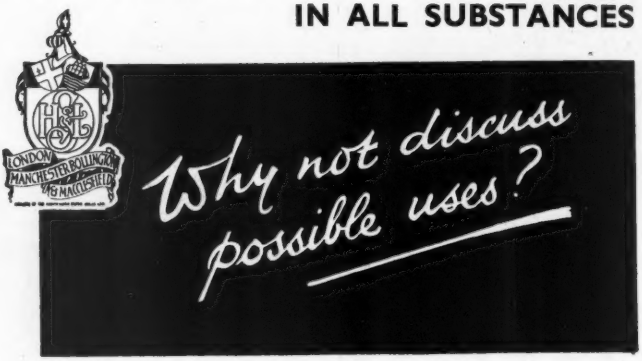

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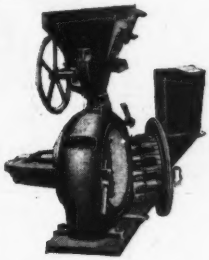

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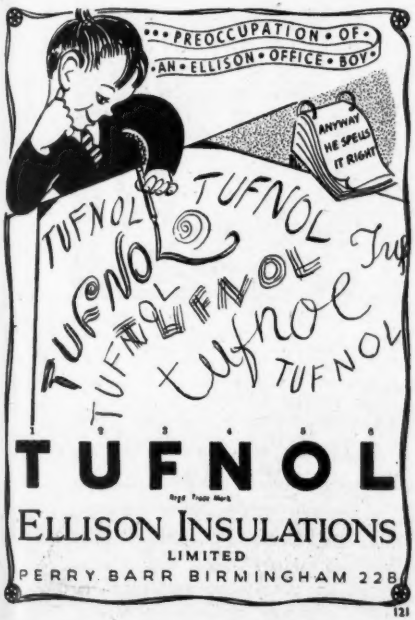

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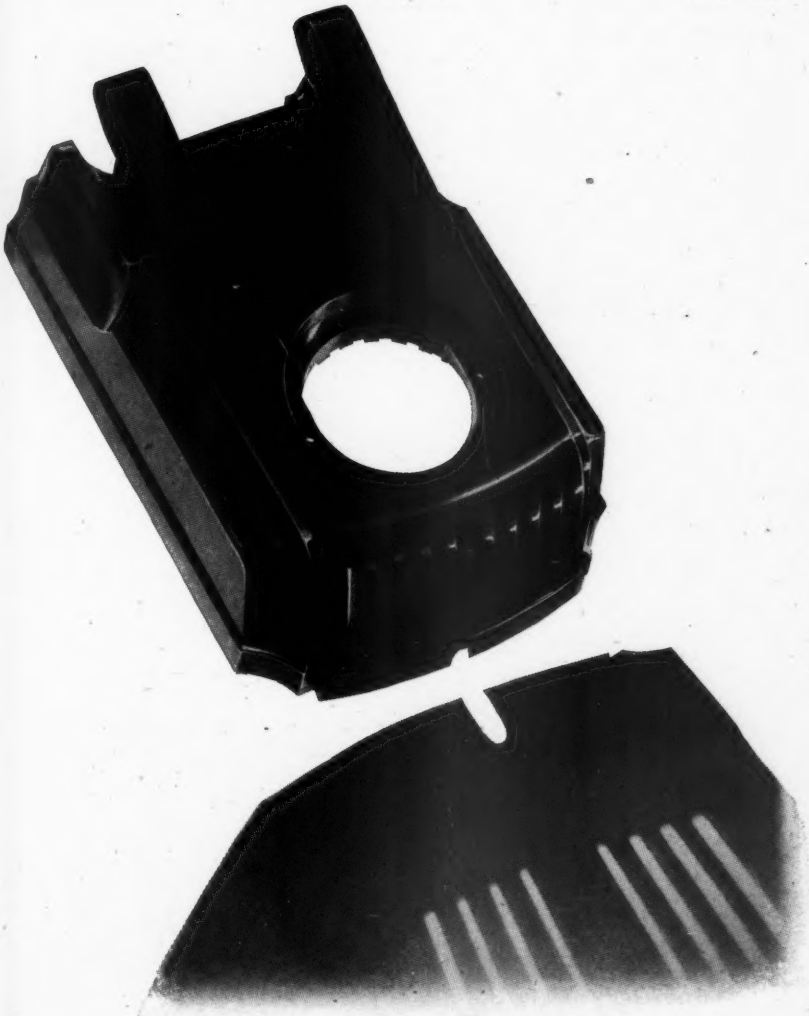

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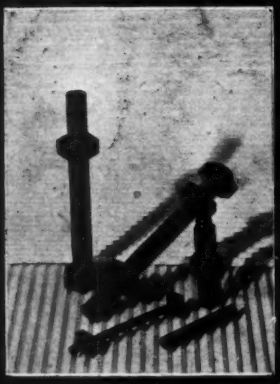

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